The Tropical Shelterwood System of Forest Regeneration

Its Development and Application in the Benin Division of Southern Nigeria and a Consideration of Factors affecting its Success.

William E. Scott Mutch, B.Sc. (Forestry) Edin.

PREFACE

In presenting this thesis I wish to thank the Government of Nigeria, and particularly Mr D. R. Rosevear, the Inspector General of Forests, for permission to use data from official reports and surveys forming part of the Forest Department records. I wish to make it clear, however, that deductions from these data and opinions given are my own and do not in any way reflect or involve official opinion in the Nigerian Forest Department.

October 1952 William E. Scott Mutch.

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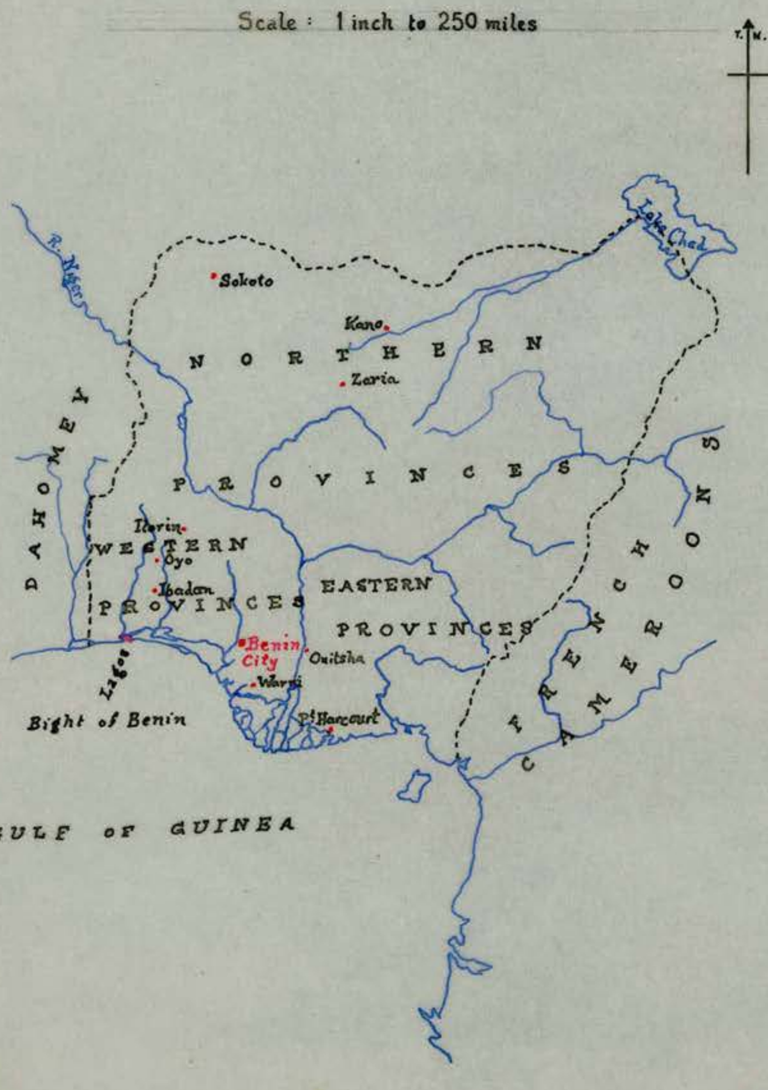
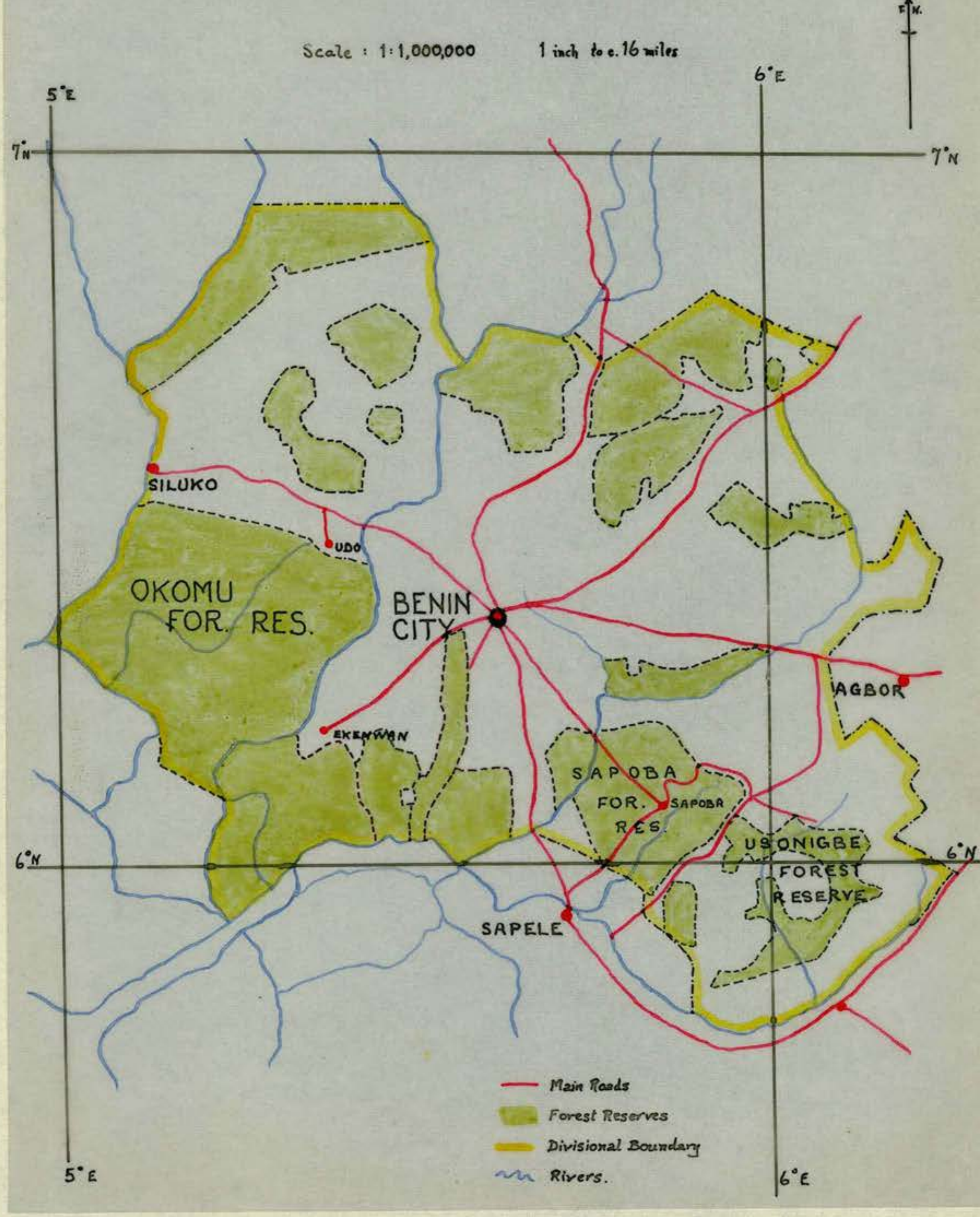


Map 2 **SKETCH MAP OF BENIN DIVISION**



INTRODUCTION

It is the purpose of this paper to give a description of the development of a system of natural regeneration for the Benin forests, to measure the success of the work, and to set out some of the factors which appear to limit or to assist the regeneration.

Between the latitudes 6 and 7 degrees north and the longitudes 5 and 6 degrees east in Western Provinces, Nigeria, is situated Benin Division, the most southern and western of the four political Divisions which together form Benin Province. The area of Benin Division is approximately 4,000 square miles, and in 1931 (the latest census figures available) the population was taken to be 111,000, although there is no doubt that during the last two decades this latter figure has greatly increased due to a rising birth-rate and an influx of labour, mainly from the south and east, to the prosperous rubber estates and expanding timber industry. The provincial and divisional capital, Benin City, lies in the centre of the Division. With a population of over 20,000 it is the hub from which radiate the several roads which serve the many small and few large villages of the area and which link the capital with neighbouring Provinces.

GEOLOGY. Crystalline rocks (the "undifferentiated basement complex" of gneisses and granites) occur in the extreme north-west of the Division, but the remainder is entirely sedimentary, being part of the extensive Benin Sand Series. In parts this formation consists of a homogeneous layer of quartz sand several hundred feet thick, but the Benin Sands may be part of the Lignite Series, in which unevenly distributed strata of sandstone, shales and clays occur in the red sands.

RAINFALL AND DRAINAGE. The average rainfall of the whole Division is probably about 75 inches per annum, distributed in the typical two-peak fashion of the coast of West Africa. The rainfall in the south averages 110 inches per annum (probably higher in the extreme south-west) but that in the extreme north may be as low as 60 inches. The figures for Benin City show that the months of November, December, January and February have precipitation below 3 inches per month, but the relative humidity (especially in the forest) remains fairly high throughout the year, and the effect of the dry Harmattan wind from the north is weak and is obvious on only very few, isolated days. The table (No. page 3, shows average rainfall, temperature and relative humidity figures for Benin City which is not itself in the forest. Within the forest the mean relative humidity, particularly at 3 p.m., is higher and probably without such large fluctuations between months. (See Table 1. p. 3).

The area of the Benin Sands is characterised by a scarcity of streams and the rain-water appears to drain to considerable depth, the rivers flowing in deep trenches cut below the general level of the almost flat plain. Except on land which has been completely cleared of vegetation there is little run-off, and the streams, fed by underground drainage, generally hold deep and very clear water. Chukwuogo and other writers have stressed the severe water shortage which exists in the country districts, in the dry season, away from the limited number of streams.*

* E.M. Chukwuogo: Farm and Forest. Vol. VIII. No. 2, 1947. p. 57, etc.

TABLE 1.

RAINFALL, TEMPERATURE AND RELATIVE HUMIDITY MEANS.

BENIN CITY

Average for Ten Years, 1922 to 1931.
Height above Mean Sea Level 275 feet

MONTHS	MEAN RAINFALL		TEMPERATURE		RELATIVE HUMIDITY	
	Amount in inches	Number of days	Mean maximum	Mean minimum	Mean at 9 a.m.	Mean at 3 p.m.
January	0.79	3	89.9	68.4	84	59
February	1.29	4	91.8	70.3	85	61
March	3.37	7	92.2	71.3	84	61
April	6.79	12	91.1	70.7	85	66
May	8.33	14	90.6	70.9	85	65
June	12.36	20	88.1	70.3	88	69
July	11.44	19	85.2	69.6	89	73
August	8.64	19	84.1	69.8	90	75
September	12.23	23	85.4	70.7	89	70
October	9.49	18	88.3	71.3	88	67
November	2.99	6	90.8	71.6	86	63
December	0.65	1	90.3	70.9	84	63
Yearly Means	78.37	146	89.0	70.4	86	66

FARMING. The local food-farming technique involves the practice of a bush-fallow system; the number of years for which a farm is cropped is small, usually two, or possibly three years if the land proves to be of high quality, and this is an index of the rapidity at which the Benin Sands lose their fertility after the removal of the forest vegetation. The farmer cuts, heaps and burns almost every tree on the new farm, and this practice of leaving no high shade has important ecological and economic repercussions. There is a sharp contrast with the practice in other parts of West Africa where the largest trees remain as a high shade, an important reservoir of timber, a source of seed and a skeleton of forest structure.

There are practically no cattle in the Division owing to the susceptibility of all but a few strains to trypanosomiasis. The most common domestic animal is the goat, which is here a village or compound animal, living by scavenging and seldom, if ever, found either in forest or farm.

An important plantation crop of the Division is rubber and considerable areas have been planted with Heavea brasiliensis. During the 1939 - 45 war the plantations prospered, and were largely extended owing to the inflated price of rubber following the Japanese occupation of Malaya, but the present prices are subject to large fluctuations.

TIMBER. By far the most important industry, apart from food-farming for local use, is timber working. On this trade, whether for the export market or the Nigerian market, the prosperity of Benin largely depends.

A result of the rising standard of living of many Nigerian people, and the growing needs of industry in West Africa and abroad, is that the demand for Nigerian timber has increased. At the same time the area of non-reserved forest (forest land not included in Forest Reserves) has been greatly reduced in the last fifteen years owing to the destructive work of farmers and the planting of permanent cash crops. The supply of timber outside the gazetted Reserves dwindled rapidly, particularly because of the clear-felling technique of the farmers, and the Forest Department was faced some years ago with the need to allow the exploitation of Forest Reserves to begin; such exploitation had to be accompanied by regeneration, either artificial or natural. Artificial regeneration, while important in certain limited areas and for special purposes, could not be attempted on the scale necessary to ensure the future of the forests and thus natural regeneration had to be attempted on an enormous scale.

The intention in this paper is to describe briefly the technique of natural regeneration adopted and to examine in some detail the success obtained in different forest associations in a single compartment with the object of assessing the suitability of the technique for the maintenance of the forest.

THE FOREST

The whole of the Division lies within the belt of closed tropical rain forest, although there are some areas of fresh-water swamp type and small parts in the south (the largest is known as the Sobo Plain) which are completely unforested and carry a dense grass vegetation. An account of a floristic survey in these open clearings has been given by Keay and Onochie.* *

Most of the forests of Benin are of great commercial value and approximately 39% of the Division has been secured as Forest Reserve. The number of tree species represented is very large and the conditions governing the regeneration of all but a few are not understood, and those few very imperfectly. When mature this forest is said to be multistoried with very little creeper, climber or ground vegetation, but such areas are difficult to find; almost every part appears to have been disturbed in the past and heavy creeper and climber growth following exploitation or farming is a feature of the Benin Forest.

The structure of most of the reserved high forest is as follows.

1. GROUND VEGETATION and CREEPER GROWTH of varying density according to the maturity of the forest and the light available. The majority of the plants in this group are members of the families

* * R.W.J. Keay and C.F.A. Onochie: Farm and Forest. Vol. VIII. No. 2. 1947, p. 71. etc.

Commelinaceae, *Acanthaceae* and *Marantaceae*. Members of the *Apocynaceae*, *Araceae* and some climbing palms also occur. Patches of tangle containing *Acacia pennata*, *Acacia ataxacantha*, *Oncocalamus* spp. and *Calamus deeratus* are locally important. The ground vegetation is usually sufficiently dense to prevent easy access on foot and except on paths the use of a heavy knife is frequently, but not constantly, required.

2. A SHRUB LAYER from 5 to 15 feet high, consisting of such species as:-

Xylopia sp.	*Randia* spp.
Drypetes chevalieri	*Diospyros barteri*
Rinorea spp.	*Ouratea* spp.
Ochna sp.	*Dichapetalum* sp.

3. A MIDDLE STOREY, 25 to 50 feet from the ground, consisting of:-

Anonidium mannii	*Diospyros crassiflora*
Diospyros insculpta	*Macrolobium macrophyllum*
Strombosia grandifolia	*Picralima nitida*
Drypetes principum	etc.
Enantia chlorantha	

4. AN UPPER STOREY, 60 to 100 feet from the ground, consisting of:-

Strombosia pusulata	~~*Maba chrysantha*~~
Pausinystalia spp.	*Diospyros confertiflora*

Hylodendron gabunense	_Aningueria robusta_
Hannoa klaineana	_Chrysophyllum_ spp.
Trichilia prieuriana	etc.
Scottellia coriacea	

In both the middle and upper storeys the crowns of the trees normally form a canopy. Those in the middle storey tend to be wide-spreading and cast dense shade; those in the upper tend to be narrow and flame-shaped (irrespective of the density of stocking) and cast relatively light shade.

5. EMERGENTS, whose crowns project out of the upper canopy at irregular intervals, rising commonly to a height of 140 feet and sometimes to almost 200 feet. When the emergents are mature their crowns tend to be very wide-spreading; they do not normally touch the crowns of adjacent emergents and do not form a continuous canopy. The species in the emergent class include almost all the important timbers of this forest, such as:-

Khaya ivorensis	_Lovoa klaineana_
Guarea cedrata	_Guarea thompsonii_
Entandrophragma angolense	_Entandrophragma cylindricum_
Entandrophragma candollei	_Gossweilerodendron balsamiferum_
Triplochiton scleroxylon	_Sarcocephalus diderrichii_
Mimusops heckelii	_Celtis zenkeri_

<u>Lophira procera</u>   <u>Piptadenia africana</u>

etc.*

All species given as examples in each canopy do not necessarily (or usually) occur in one locality, and although the structure of the Reserved forest is similar in all parts of the Division, the floristic composition varies considerably.

Among the Emergents alone, in the Sapoba and Usonigbe Reserves in the south-east of the Division, <u>Gossweilerodendron</u> and <u>Triplochiton</u> are common, while the two <u>Guarea</u> species are relatively uncommon and <u>Lophira</u> is often absent; in Okomu Forest Reserve, only 40 miles away in forest which appears similar and whose site conditions are almost identical, <u>Lophira</u> and <u>Guarea</u> species are very common, while <u>Gosswelierodendron</u> and <u>Triplochiton</u> are rare or absent. The reason for such difference is difficult to understand, and there is still a large amount of ecological work to be done in this vegetational type.

Patches of climber or creeper tangle are locally common throughout the Benin Forests and in certain areas may cover a considerable percentage of the total area. Conditions in these tangle patches (or "iloi" in the vernacular) vary from a fairly open area with grass and small grazed bushes covered with creepers, through a dense mass of

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* It must be remembered that the forest is a living community subject to the normal processes of change; death, decay, growth and replacement are always in progress. The ground vegetation, besides the plants which reach maturity at the Herb level, contains tree seedlings. Similarly the Shrub layer contains saplings of the Middle and Upper canopy, and Emergent species; the Middle canopy contains poles of the Upper canopy and Emergents; and the Upper canopy, immature Emergents.

creepers and climbers in which small bushes form a framework, to the type in which deformed trees twenty to fifty feet high form the supports for a 'roof' of climbers and for festoons of dead and dying creeper stems and broken tree branches. Windfall and the break-up of a section of the upper canopy seem to be conditions favouring the growth of an 'iloi' patch, and although there is sometimes evidence that elephants maintain the patches by breaking trees and grazing, it is clear from the occurence of patches scores of acres in extent and totalling square miles that larger forces are responsible.

FAUNA. In the Forest Reserves in the west of the Division, i.e. Okomu, Iguobazowa, and Ohosu, elephant occur and though they are rarely seen they may be of some importance in the ecology of 'iloi' patches, as such vegetation undoubtedly supplies much of the animals' grazing. Antelopes found in Benin Forests include the Bush Cow, Bush Buck, the Black Duiker, the Yellow-backed Duiker, Maxwell's Duiker, and in the swamp regions the Situtunga. The Red River Hog occurs and there are several species of Monkey.

SILVICULTURAL REQUIREMENTS OF THE MAIN SPECIES. Because of the position which they occupy in the vertical section of the forest, it is clear that the majority of the understorey species are very shade tolerant throughout their life-cycle, but the silvicultural requirements of the of the upper storey and emergent species are more complex. A few, such as Triplochiton scleroxylon, Ceiba pentandra, Ricinodendron africanum, the Terminalia spp. and Lophira procera are intense light-demanders during the whole life of the tree, showing excellent growth in old farm areas and appearing fairly early in the natural succession of vegetation after clearing. Except for Lophira and Terminalia ivorensis they are typical of the slightly drier high forest type north of Benin, and may have extended their zone of occurrence by continual southward encroachment in farm-land regrowth in relatively recent times. A few species, to some extent Khaya ivorensis and especially Guarea cedrata among the emergents, are strong shade bearers, their regeneration being able to exist and grow slowly in intense shade. Most of the emergents, however, are able to exist in only slight shade or can tolerate heavy shade for only a short time after germination; their regeneration is very transient, dying in a few months or a year, if light is not admitted to continue their growth in their now light-demanding state.

Under mature natural forest, fairly profuse regeneration of most of the economic species can be found after a heavy fruiting, but this disappears almost entirely unless the seedlings happen to be growing in good light conditions, i.e. in or near a gap caused by wind-throw or the break-up of one of the large top canopy trees. This fact seems to be of great importance in the study of a regeneration system.

THE BEGINNING OF FORESTRY IN BENIN DIVISION

For the first twenty-five years of the present century constructive forest work in Benin was limited to the survey and establishment of Forest Reserves, the planting of some exotic species, including rubber, in plantations and the replanting of individual stump-sites with young trees to replace the fellings of the commercial firms.

In 1928 a silviculturist opened a research station at Sapoba in the south of the Division and he began trials of species, some exotic and many indigenous, in plantations largely established with the help of farmers (following the Indian practice of taungya), and also investigated the possibility of natural regeneration with modified Uniform and Group Systems.* In all this work he was limited by lack of funds and it was the acute financial position, gradually worsening from 1930 to 1933, which eventually brought the virtual close-down of the station in the early nineteen thirties.

By the year 1935 a total of 1387 square miles had been gazetted and fully constituted as Government Forest Reserves. Before the outbreak of war the Native Administration had been given full charge of these and a further 1777 square miles of Forest Reserve had been proposed.

* Details of the early work may be found in Bulletin No. 1. of the Nigerian Forest Department, "Record of Forest Research in 1928".

Unfortunately the war interrupted the work of finally surveying and gazetting this vast forest estate and when the work was continued in the post-war period it was found that a very large area of forest had been destroyed by farmers, especially by the cultivators of rubber who, in the boom of this commodity, illicitly cleared forest to establish plantations. In mid-1948 the area of Reserved Forest was 1561 square miles, and, in the belief that this figure would not be materially reduced by further excision of farm land, it was on an assumed total forest estate of 1500 square miles that preliminary management plans for the forests of Benin Division were based.

These forests are among the richest and most easily accessible in West Africa, and almost the whole of the forested land in the Division, both reserved and unreserved, is licenced to timber firms.

During a typical post-war year, while over 21,000 trees were cut for export from Benin Division, only 910 trees were cut for local use; much of the sawn timber requirement in the Division is met by re-import of timber from mills at Sapele. The trees for local use are pit-sawn, generally into 12 feet x 12 inches x 1 inch boards.

Apart from the small number of trees pit-sawn locally, the whole of the sound timber felled in the Benin forests is sent by river to Sapele, which lies a short distance beyond the southern boundary of Benin, in Warri Province. Sapele town stands on the river of the same name, near the confluence of the Jamieson and Ethiope Rivers, and although it is more than 55 miles from the sea it is accessible to ocean-going ships. Its export trade in palm oil and kernels averages about £75,000 per annum, in rubber almost £200,000 and in timber nearly £500,000. Logs come to the port by water, either in rafts or, recently, in lighters; there they may be selected for export or may be converted. Conversion machinery includes the most modern bandsaw equipment and a very large plywood mill erected in 1947; work is in hand for the installation of other saw-milling gear. The life of the whole town, which is growing very rapidly, is built round the timber trade; its prosperity depends on the forests of Benin Division and their future in turn depends on the ability to regenerate as well as to exploit them.

EARLY REGENERATION METHODS AND EXPERIMENTS

Data from the early regeneration experiments started in 1928 were by no means complete owing to the closing of the station, and a system of regeneration to be applied on a large scale could not have been based upon such inconclusive evidence as that available from the first trials of Walsh's System, the Uniform System, the Transition method and the System of Selection Groups.* The need for preparing a regeneration technique suitable for application on a large scale was fully recognised, and therefore, when the effects of the slump were beginning to lessen and money for research was more easily obtainable, it was decided to carry out more experiments designed to answer the difficult questions of rain forest regeneration.

Some of these later investigations were in the field of pure ecology, to discover the natural succession in gaps and the succession of death, decay and replacement that goes on under natural conditions in the rain forest. One series of investigations, however, was the precursor of the system now in use, the Tropical Shelterwood System; the method was named, rather obscurely, the Transition Group System and embodied the lessons learned in the earlier research in the Uniform System and the Transition Method. The plots were replicated both in the Sapoba Reserve and in the Okomu Reserve, forty miles north-west of Sapoba. The Okomu Reserve, in which very

* See Bulletin No. 1. "Record of Forest Research in 1928" issued by the Nigerian Forest~~ry~~ Department.

little exploitation had been done, was an exceedingly rich forest area, differing somewhat in floristic composition from the Sapoba type although structurally very similar.

Forest in which very selective logging had been done between 1933 and 1936 was chosen for the investigation. In Compartment 73 of Okomu Reserve only a few large economic trees had been removed, (viz: _Entandrophragma cylindricum_, _Lovoa klaineana_, _Khaya ivorensis_ and possibly a few others); _Strombosia pustulata_ had been cut for sleepers, and many small understorey trees, in the immediate vicinity of the economics and on the extraction routes, had been taken for rollers on which to pull out the heavy marketable logs. This cutting had caused a very considerable, but local, opening of the canopy, and some climber and creeper growth had resulted. The opening had also allowed the preliminary establishment of some groups of regeneration of valuable tree species, mainly of the _Meliaceae_. The assistance of these seedlings which were mainly concentrated in groups and the majority of which were only a few inches high, was the principal object of the work.

In March 1936 the following operations were carried out in the experimental strips and in a narrow "surround":-

1. Cutting all climbers.
2. Slashing all shrubs at knee height.

3. Frill girdling and poisoning of selected trees with wide-spreading dense crowns in the middle storey.

The third operation, the poisoning of "key" trees, was done with Sodium arsenite solution, a half pound of the salt in one gallon of water; the poisoning resulted eventually in the removal of about 30% of the middle storey.

One year later an assessment was made, the positions of seedlings of valuable species being plotted on squared paper, the trees forming the various canopies being identified, measured and the crown-pattern mapped, and a general description of the plot made. Again in 1939, forty-three months after the original work and thirty-one months after the first assessment, a further examination of the plot was made.

The officer who re-assessed the Okomu Reserve plot said in his report, "In general, the technique has been successful in lighting the lower layers of the forest and removing creepers and 'key' trees." The death of the poisoned trees allowed ample light to enter and many saplings responded well. Figures for the increase in height of seedlings definitely identified in both assessments showed that <u>Lovoa</u>, <u>Khaya</u>, <u>Guarea cedrata</u> and <u>Lophira</u> doubled their height with increments of 3.5 to 4.5 feet in the 31 months between assessments.

Partly from the results of this experiment it was concluded that regeneration of Nigerian rain forest could be obtained, at least when conditions were favourable as regards incidence and distribution of valuable seed bearers, etc., and the work showed that the poisoning of useless shade-casters in the middle (or upper) ? canopy could have a similar effect to a seeding felling in the shelterwood regeneration systems of temperate forests.

It was the intention of the Forest Department to continue the assessment and also to try other treatments, but the War and the resulting shortage of trained staff made this impossible. However, the experimental work was not wasted, for it was a useful step towards the successful introduction of the Tropical Shelterwood System in 1943, and the results must have influenced the minds of officers at the commencement of the large-scale operations in the Division.

THE INTRODUCTION OF REGENERATION AND MANAGEMENT SYSTEMS TO THE BENIN FORESTS

The year 1943 was an important one for Benin, Nigerian and perhaps for tropical African, forestry. In that year there came to Benin two officers whose experience and foresight made possible the introduction of regeneration and management plans for the Benin Forests.

Mr. G.W. Somerville had been sent to Nigeria when Malaya was overrun by the Japanese. He was seconded to Benin Division and shortly after he arrived the valuable timber tree, _Triplochiton scleroxylon_, began to fruit heavily for the first time since 1936. Mr. Somerville had experience of the application of a rain forest regeneration technique in very different forests in Malaya and he decided that advantage should be taken of this fruiting. His beginning was not timid, as shown in his letter to the Chief Conservator of Forests, announcing the start of operations.

"Obeche* is germinating in some test patches which I had cleared and I propose to start poisoning of a large proportion of trees in the lower storeys.

"The area so far climber-cut is about six square miles..." This was in the Obeche Series of Sapoba Reserve.

The operations detailed later started with several initial

* Obeche: the Benin vernacular name for _Triplochiton scleroxylon_.

disadvantages:-

a. Lack of knowledge of the best areas to treat.

b. Lack of previous treatment.

c. Removal by licensees of Triplochiton trees which had reached fellable girth, thereby reducing the number of seed-bearers.

d. Lack of staff, especially trained staff.

e. Shortage of trained labour.

In addition, doubts were expressed by some officers of the Department as to the suitability and prospect of success of the poisoning method of establishing regeneration, and as to whether any useful regeneration could thrive under the tangled growth existing in parts of the area dealt with. The doubts and difficulties resulted in the calling of a conference of four forest officers to discuss the position; Mr. Somerville stated what had been done.

Quadrat counts had revealed Triplochiton seedlings present at rates from 200 to 6,000 per acre, varying with distance from the nearest mother tree, and where treatment had been made. Much of this flush of seedlings was flourishing. Where there had been no treatment the regeneration had disappeared.

Treatment consisted of climber cutting and clearing the undergrowth to waist height, followed, after an interval of approximately two months, by poisoning all non-economic species in the middle storeys.

Patches of "iloi" (Acacia pennata tangle) were left untreated and where the top storey was only 20 feet from the ground it was left untouched, irrespective of species. The supervision was undoubtedly inadequate and in certain areas the inevitable mistakes occurred. The direct costs of both climber-cutting and poisoning were 11d per acre, the gangs being allocated a task amounting to 1 acre per man-day.

Commenting upon the fear expressed that the operations would result in a spread of the thorny, creeping weed Acacia pennata, Mr. Somerville stated his view that it was impossible to create conditions for the regeneration of a strong light-demander like Triplochiton without risking the creation of optimum conditions for Acacia pennata at the same time, but that risk had to be accepted.

The conference felt that the Forest Department had to make experiments on an extensive scale to discover some means of naturally regenerating the forest, and that the risk was justified. It was agreed that the work should go on, that close observations should be made and that other areas, for Meliaceous regeneration, should be opened.

This meeting of officers and the confirmation of its views by the Chief Conservator gave Mr. Somerville his mandate to continue, which he did. Because of the lack of seed-bearers, lack of experience in poisoning the unwanted species (many of which were found to be very poison-resistant), lack of trained supervision staff and trained labour, the initial work in the Obeche Section at Sapoba was not as successful as was hoped, but the Nigerian Forest Department must remain indebted to this officer for demonstrating that extensive regeneration working was a practical and economic possibility. However, the knowledge that the Benin Forest could be regenerated would have been little use had a change not been made in the system of licencing and timber working.

Under the former system of licencing, timber firms, all holding relatively large areas of land, were able to work a system of highly selective logging, and in this way were able to maintain a very valuable export trade in large selected round timber. The Forest Department had virtually no control over the companies as to the opening of working areas, and as a new species became marketable the companies were able to go back repeatedly to an area previously worked, irrespective of the fact that the Forest Department, believing that logging had ceased, might have started regeneration work. It was almost impossible to organise regeneration either prior to, or following, such exploitation.

Late in 1943 Mr. F.S. Coller, C.B.E., then the Conservator of Forests, South Central Circle, sent to the Chief Conservator an important memorandum on the logging trade in his area, and his opinions on the future of the forests. Because of the uncertainty of the exact areas of workable timber in the Division, and because of the certainty of drastic reductions in the effective areas of reserved forest during the impending consolidations, it was essential to make the work of the timber industry and the Forest Department more intensive. Mr. Collier, after examining the available data on the content of the forests, came to these important conclusions:-

1. The export trade in large selected logs must eventually die.

2. Intensive local saw-milling must largely replace the export trade.

3. During the somewhat lengthy transition period between (1) and (2) above

(a) The country as a whole could not afford to lose entirely the log export trade, much more valuable to Nigeria than the Benin revenue figures suggest.

(b) The Department must help to establish local markets to absorb the secondary timbers, the non-utilisation of which he considered to be a great obstacle to successful regeneration of the forest.

(c) Provision must be made for the possibility that exploited areas might fail to regenerate naturally. Within the reserves sufficient timber for 100 years must be held and the annual cut of the exploiters must be controlled. Outside reserves "salvage fellings" should be encouraged; i.e. there should be almost uncontrolled exploitation so that the firms and the Benin Native Administration might benefit from the timber felled before the farmers, who could not be controlled, destroyed the timber.

Mr. Collier then considered the regeneration of the forests. He supported the theory that the bulk of the present forest had been regenerated in the past by local and inefficient farm clearing and that it consists not of a true selection foresty, X but of a mosaic of groups, each group almost even-aged and resulting from a clear-felling or from a very great opening of canopy. He suggested that :-

1. because legal rights of the concessionaires might prevent any conversion to a new system of working in a period less than 25 years, the concessionaires should be given every inducement to fell on unreserved land, to the exclusion of reserved areas as far as possible;

2. reserved areas should be grouped, each group to be worked under one simple scheme, which should allow for a rotation of 100 years and a nominally clear-felling compartment system with regeneration by <u>taungya</u>. This would provide that no more than

1/100th of the total area of reserved forest would be felled annually. Intensive felling would be encouraged by pressure, removal of girth limit, and by the firms' knowledge of their felling area limits. Loss of overmature stock in the remainder of the forest would be avoided by allowing advance fellings with a very high girth limit, accompanied by regeneration by stump-site planting.

It was stated that the object of any plan must be to convert the Benin forests from the "unmanaged" state with a very long rotation, to a "managed" state with a reasonably short and economically profitable rotation, the ultimate object being to secure for the forest owners, the Benin Native Administration, the maximum revenue from outside Nigeria by encouraging export <u>in perpetuity</u>, while at the same time supplying all the local timber and forest produce requirements of the people.

Briefly, Mr. Collier's plan, strictly confined to the estimate of 1500 square miles of securely reserved forest, reads as follows:-

1. The suggested rotation shall be 100 years, divided into four periods, each of 25 years.

2. In period I, one-quarter of the working circle, 375 square miles of forest, shall be exploited and regenerated; i.e. the total annual cut of all firms must not exceed 15 square miles. The change from extensive to intensive working must not

result in a crippling of the firms and a large decrease in forest revenue (the virtual defeat of one of the plan's objects); the change can be covered by logging outside the reserves and by the marketing of more species, but it must be complete by the end of period I.

3. The regeneration work undertaken by the Forest Department shall be of two types:-

(a) Artificial regeneration by taungya or line planting on secondary farm-bush or exploited areas.

(b) Natural regeneration by pre-exploitation treatment on areas still carrying high forest, a climber-cutting being followed by a seeding poisoning of useless species, and, when regeneration is established, the operation being completed by a final felling by exploiters. After the final felling exploiters can have no further access to the area.

The plan received both support and much criticism from the timber firms, but with modifications and additions it received approval and formed the basis for the actual Working Plans of the Benin forests which have since been written. The acceptance of this scheme, the resultant changes in the method and intensity of exploitation, and the development of the Tropical Shelterwood System by the Forest Department, from the attempts at Triplochiton regeneration already described, made the systematic regeneration of the Benin high forest a practical possibility.

Soon after the events and decisions described in the foregoing pages, a simple working scheme was evolved. With the rotation provisionally fixed at 100 years, the working circle (the whole of the reserved forest) was divided into four periodic blocks and firms and individuals with licences and timber agreements were each allowed an annual coupe in proportion to their total holdings. Arrangements were made for the licencees to declare and define their areas of working five years in advance, so that regeneration might be correlated with, and might preface, the exploitation. The licencees chose their felling areas after studying enumeration data, the sites of labour camps, etc. and it appears that, in the fear that the change from extensive to intensive working necessitated by the drastic limitation of area would result in their being short of fellable timber, they tended to select the richest known areas for the early years of working. It was an obvious choice to make, but it had the effect that regeneration operations began in some of the richest timber areas; since the species whose regeneration is most desired are the same as the species at present most valuable as timber, this means that there is no lack in such areas of seed trees. Also, the most valuable timber areas tend to be those least recently disturbed by previous timber working and farming and so they are generally areas of forest displaying the multi-storey, creeper-free characteristics mentioned on page 6 as typifying this vegetation in its near-climax stage. It is important to note that most of the early Tropical Shelterwood System work was done in this "clean" type of forest.

THE TROPICAL SHELTERWOOD SYSTEM

THE METHOD OF WORKING.

Before timber working or regeneration operations commence a necessary preliminary is the demarcation of compartments. This may be done either by the Forest Department or by the timber firm; the reserve is normally divided into compartments one mile square, although obviously the boundary compartments are frequently irregular in shape.

Following this original division the concessionaire is bound by the terms of his licence to carry out a 100% enumeration of economic trees, marking the base of each economic with scribed code letters and figures to show the compartment, the species, and the serial number of the tree in that compartment. The firm must then state in what order the compartments will be exploited; i.e. they must choose the coupes at least 5 years in advance so that the Forest Department may know in which compartments the T.S.S. work should be started. The operations are:-

Demarcation	Year 0
1st Climber Cutting	" 0 (Rainy Season)
1st Poisoning	" 1 (Dry Season)
2nd Climber Cutting	" 1 (Rainy Season)
1st Regeneration Count	" 1 (Rainy Season)
2nd Poisoning	" 2 (Dry Season)

1st and 2nd Cleanings	Year 2 (Rainy Season)
3rd and 4th Cleanings	" 3 (Rainy Season)
2nd Regeneration Count	" 3 (Rainy Season)
5th Cleaning	" 4 (Rainy Season)
Exploitation	" 5 ———

Post exploitation cleanings as necessary.

1. Demarcation. When a compartment is scheduled for pre-exploitation regeneration treatment under the Tropical Shelterwood System the first task is the sub-division of the large compartment which is usually one mile square. The timber firm, for purposes of enumeration, has probably already cut the square by one north-south line and three east-west lines known as quarter-lines, to give eight equal rectangles 40 chains by 20 chains. Immediately prior to the start of regeneration operations thirty-one north-south "grid" lines are cut by the Forest Department to divide the mile-square compartment into 32 strips, each of 2½ gunter chains width. This is a convenient frontage for the working of one gang, and makes the calculation of areas treated an easy task, since each mile-strip is 20 acres, sub-divided into 5 acre plots by the quarter-lines. In the interests of economy these "grid" lines are made as narrow and as cheaply as possible, since they are temporary and, apart from easing administration and serving as guides, are of no use in the real task of regenerating the forest.

2. <u>1st Climber Cutting</u>. In the early days of the application of the Tropical Shelterwood System in Nigeria, it was believed that this operation merely allowed freedom of movement within the forest, was only a preliminary to the real regeneration openings, and in itself did not aid seedling growth. The amount of shade cast by climbers had not been fully realised and later it was found that in some compartments the cutting of the lianes and of the low creepers and monocotyledonous ground flora resulted in a considerable lightening of the forest floor. Therefore in June 1947 it was agreed that 1st Climber Cutting would be regarded as "a definite silvicultural operation, including the clearing of ground flora to ankle height." This was done because it was thought that the high shade cast by climbers and the very intense local shade cast by creepers, monocotyledonous weeds and small shrubs was a real hindrance to the growth of tree seedlings. The following are now cut.

(a) All climbers.

(b) All ground vegetation (except seedlings of economic tree species) down to ankle height.

(c) Shrubs which may be felled with three matchet strokes.

(d) Bent and damaged seedlings of desirable species may be coppiced.

At present no definite season is stipulated for Climber Cutting, but as it immediately precedes a dry-season operation it is normally done in the rains.

3. <u>1st Poisoning</u>. This is the equivalent in the Tropical Shelterwood System of a Seeding Felling in the temperate Shelterwood Systems, and consists of the removal by poisoning of all or part of the middle canopy, in order to admit to the forest floor sufficient light to encourage the growth of the desired regeneration. The poison used is a solution of 1 lb of commercial Sodium arsenite in a gallon of water, and it is applied from a one-gallon can with a narrow spout to a frill girdle cut into the sapwood of the tree. Since the arsenite is highly poisonous to human beings, careful precautions must be taken to prevent its internal consumption by labourers.

The frill girdle, normally made at knee height, is cut with a small hand-axe to a depth of about one inch into the sapwood. The girdle must be continuous round the stem, breaking the cambial layer everywhere, and made entirely with downward directed axe cuts so that a channel is formed in which the poison may lie. An additional or secondary girdle, cut at least one foot above the main one, is used on species which are poison resistant; it is not a true frill nor so elaborate as the main, being only a ring of single axe cuts made downwards into the sapwood; its object is to increase the vertical height of cambium killed immediately by the poison, making it impossible for cambial tissue to occlude the poisoned wound. It is essential both in the main and secondary girdles that the cuts should be continuous or overlapping round the bole. The poison is poured into the girdle when the latter has been cleared of chips and it is always stressed that the solution should be poured on to the upper side of the frill continuously round the bole to ensure that no section of the stem is untreated; the blue colour given by the Copper sulphate (added in the anhydrous state to the dry powder by the manufacturers) greatly helps the labourers in the actual application and eases the task of checking that the work is being done effectively.

In the past it was thought desirable to open the canopy as little as possible, compatible with the primary object of assisting the tree regeneration, so that the area would not be invaded by climber and creeper growth. This has always been recognised as very difficult and the view is now fairly generally held that it is practically impossible to make an effective opening for the benefit of tree seedlings without encouraging climbers to the same extent; i.e. the majority of the invading climbers and the majority of the desired tree species appear to have such similar light requirements as to make differential assistance impossible.

In order to economise in poison some of the smallest trees to be removed may be felled, but this must be done with discretion since a great advantage of poisoning over felling is that it results in a gradual opening of the canopy, avoiding sudden changes in humidity and light intensity which may be injurious to the tree seedlings. Moreover, when trees are poisoned the forest floor does not become a wilderness of fallen crowns; the leaves, followed by the twigs and branches, fall piecemeal and rotten to the ground over a period of months and they neither break much regeneration nor impede progress through the forest.

But there are several disadvantages to the method of poisoning. The first is the high cost of the Sodium arsenite; the bulk of that bought in the years 1945 to 1948 cost more than £100 per ton, i.e. about one shilling per pound. Applied at an average rate of $\frac{3}{4}$ lb per acre in each of two operations over 9,600 acres per annum the annual requirement for Benin Division is about $6\frac{1}{2}$ tons of Sodium arsenite.

The second disadvantage is the great variation in the time taken for different species to die after treatment, and the behaviour before death. Some species react in a very short time (leaves may begin falling within a day) while others, typified by the very common dense shade-casting Anonidium mannii, may take months to die and before dying produce apparently abnormally large quantities of fruit. The time taken for trees of the same species varies greatly also, apparently somewhat with season and certainly with the thoroughness of the work. The following table gives average times for death of species after dry season poisoning and careful work.

VERY SLOW.

Allanblackia floribunda	3 months
Anonidium mannii	3 months to one year
Buchholzia coriacea	Rarely dies in one year
Grewia coriacea	Rarely dies in one year
Hymenostegia afzelii	Rarely dies in one year
Panda oleosa	3 months
Strombosia grandifolia	3 months
Trichilia spp.	Rarely dies in one year

SLOW

Calpocalyx brevibracteatus	2 months
Funtumia africana	2 months
Irvingia gabonensis	2 months
Maba chrysantha	2 months
Newbouldia laevis	2 to 3 months
Randia cladantha	2 months
Scottellia spp.	2 months
Staudtia stipitata	2 months
Sterculia rhinopetala	2 months
Sterculia tragacantha	2 months
Treculia spp.	2 months

MEDIUM

Antrocaryon spp.	1 month. Not often poisoned
Ceiba pentandra	1 month. Not often found

Celtis spp.	1 month
Combretodendron africanum	1 month. Not often poisoned
Conopharyngia spp.	1 to 2 months
Diospyros confertiflora	1 month
Diospyros atropurpurea	1 month
Diospyros piscatoria	1 month
Hannoa klaineana	1 month. Not often poisoned
Hylodendron gabunense	1 month
Lannea acidissima	1 month. Not often poisoned
Pachylobus balsamifera	1 month (very variable)
Pausinystalia johimbe	2 weeks to 2 months (very variable)
Polyalthia suaveolens	6 weeks
Sterculia oblonga	1 to 2 months
Tetrorchidium didymostemon	3 to 4 weeks

RAPID

Barteria nigritiana	2 weeks
Bridelia spp.	2 weeks
Carapa procera	3 weeks
Diospyros insculpta	2 weeks
Enantia chlorantha	2 weeks
Fagara spp.	2 to 4 weeks
Harungana madagascariensis	2 weeks

Lecaniodiscus cupanioides	2 weeks
Macaranga barteri	2 to 3 weeks. Infrequent in high forest.
Musanga smithii	3 weeks
Myrianthus arboreus	3 weeks
Sersalisia micrantha	3 weeks
Trema guineensis	2 weeks
Vitex spp.	2 weeks
VERY RAPID	
Garcinia polyantha	Less than 1 week
Randia spp. (excluding R. cladantha)	Less than 1 week

The inclusion of a species in the lists above does not imply that it is always poisoned and several species given are not common in the type of forest which is being regenerated by Tropical Shelterwood System in Benin Division.

In the system as applied now First Poisoning is a dry-season operation, the arguments for this being (a) that heavy rain might wash the solution from the frill girdle and (b) that trees poisoned in the dry season will die towards the beginning of the rains when the chance of damage to seedlings by insolation is much less. The second argument appears to be valid, but the first is debatable, and small experiments carried out at the beginning of the rains indicated that poison-resistant species are easier to kill when the trees are actively growing. This may be due to the transmission of the arsenite rapidly by sap flow to the leaves, etc., whereas in the dry season there may be a tendency for the salt to kill the tissues immediately round the girdle and, since these are no longer available for sap transmission, to remain there for a long period, only slowly finding its way to the crown. This view is supported by recent work on plant poisons done in the United Kingdom and the United States of America.

4. <u>2nd Climber Cutting</u>. This operation is done in the rainy season following the initial opening of canopy by poisoning, and is the first attempt to keep in check invading creepers, climbers and monocotyledonous weeds. It is in fact a cleaning combined with the cutting of any climbers overlooked in the 1st Climber Cutting. The remarks made on the 1st Climber Cutting apply to the Second also.

5. <u>1st Regeneration Count</u>. This is done immediately after the 2nd Climber Cutting so that the task of finding seedlings may be easier. Not only small seedlings are included in the count, since the object is to assess the total regeneration including advance growth up to one foot in girth. Three classes are used for this purpose:-

Up to 3' in height

From 3' to 10' in height

From 10' in height to 1' in girth B.H.

So that the effect on the results of dense clumps or groups of seedlings will be lessened, and to give a clearer estimate of seedlings expected to survive each other's competition for some years, only one plant of two or more standing within six feet of one another is counted.

With a member of the junior technical staff doing the booking, a chain of labourers across the strip does the counting of the seedlings. Plants in the first and third classes are called and booked individually; the second group is counted by plucking one leaf (or leaflet) from each plant and booking at the end of each strip. A minimum of forty well-grown seedlings per acre, well distributed, was considered satisfactory in the early days of working but totals far in excess of that are normally obtained, and in view of possible losses during exploitation this is very desirable.

6. <u>2nd Poisoning</u>. Carried out in the dry season this is an opportunity to make further openings in the canopy where the first has been over-cautious and to repoison such trees as were treated but have failed to die, either because they are naturally very resistant or because a labourer has failed to do his work properly. It is to some extent the equivalent of a Secondary Felling in the temperate Shelterwood System. Figures from a particular compartment of the Okomu Reserve show that in a 1st Poisoning 188 trees per acre were treated and in the 2nd Poisoning in the same area 44 trees per

acre were treated. In Sapoba Reserve there was not such a large reduction, mainly because the areas were not under the same local supervision and conceptions of the correct initial canopy opening differ.

7. Cleanings. (Pre-exploitation) and 2nd Regeneration Count. While it is unlikely that any further canopy opening will be necessary after the 2nd Poisoning if the early operations are done carefully, it seems to be essential in the Benin forest to make fairly intensive cleanings or, more properly, seedling assistances, before exploitation. These are done twice yearly in years 2 and 3 of the system, normally in June and September. Their intensity depends entirely on local circumstances, such as the number and height of the seedlings and on the necessity in certain places of encouraging recently germinated seedlings.

After the 4th Cleaning a 2nd Regeneration Count is made; the method is the same as for the 1st and the object is to obtain figures with which a comparison can be made with the regeneration present two years previously. It is probable that these Regeneration Counts will not be a permanent feature of the regeneration system, but in these early years of its development, when knowledge of results and techniques is scanty, the counts are necessary and an obvious way in which relevant data can be gathered.

The 5th Cleaning will normally be the last one before exploitation, though in the original plans for the Tropical Shelterwood System provision was made for cleaning every four years (in years 8, 12, 16, etc.) until exploitation. It seems unlikely that it will be possible to obtain a lead of more than the present five years of regeneration before exploitation and it is doubtful if a greater lead would be desirable.

Post-Exploitation Cleanings. The departmental pamphlet on Tropical Shelterwood System, written almost at the start of the Nigerian application, says:

"A cleaning should be carried out in from 6 months to a year after exploitation has ceased in order to free any regeneration which has been trapped and to coppice any saplings which have been broken. A second cleaning should be undertaken after an interval of two years, and thereafter the area should be cleaned about five-yearly until the young crop is twenty years of age from the time of the 1st opening of the canopy." Sufficient experience of post-exploitation cleaning requirements has not been obtained to allow a general rule to be made. At present, to each Forest Guard engaged in the measurement and volume assessment of timber during the exploitation of the compartments in which the Tropical Shelterwood System has been applied, is attached a labourer whose duty it is to free or coppice trapped, bent or broken seedlings. As a Forest Guard has to visit every stump and road no badly damaged regeneration should be left unassisted. This seedling assistance will probably be followed by a more general cleaning and the indications are that the compartment may then be left until regeneration has reached a height which will enable labourers to go underneath the crowns to do a climber cutting in the pole crops.

It must be noted that only under exceptional circumstances are emergents or true upper-canopy trees poisoned during the opening operations, and that it is anticipated that the whole of the exploitation will be carried out at one time. This does not seem to be the case in Malaya, the other colonial territory where a similar system is widely applied in the regeneration of natural forests. Also Malayan experience during the war has shown that regeneration, uncleaned because of the Japanese occupation, survived and the Forest Department is considering whether the cleanings are really necessary for success. It appears, however, that conditions in the two forests are very different and it cannot be assumed that because cleanings are not necessary in Malaya they may be omitted entirely from the West African technique.

It is often asked if seedlings are 'induced' by this Shelterwood system of regeneration, or if the bulk of the seedlings found in Regeneration Counts are 'advanced growth'. It is a fact that the seeds of the Emergent and Upper Storey species do germinate in vast numbers under natural conditions in forest which is silviculturally untreated, and the writer suggests that the treatment merely assists literally natural seedlings. Also, the writer believes that advance growth is not generally important since the term should only be used for established seedlings present before the commencement of regeneration operations by the forester. It is normal to find in this forest relatively small numbers of saplings of highly shade-tolerant species such as Guarea cedrata, and (if one visits the forest in the weeks immediately following a fruiting of the main species) almost astronomical numbers of young seedlings of every species from the heaviest shade-bearer to the most intense light-demander. The life-expectation of the latter must be numbered in days, only those which happen to germinate near an existing gap having any hope of survival. Although it is certainly an over-simplification of the problem it appears generally true that the heavy shade-bearing trees produce seed in the expectation of some of their progeny being able to survive in the normal light conditions of the forest ready to take advantage of the formation of a gap (and therefore increased light) many years ahead, while the non-shade-tolerant species produce seed in the hope that some of their progeny will happen to germinate in or near an existing gap in the canopy, that being their only chance of survival apart from human interference.

Thus the silvicultural treatment which the Forest Department seeks to apply frees checked advance growth and permits later germinations to grow unchecked, the latter being the more important in terms of numbers of seedlings.

A list and description of the various operations carried out in the Tropical Shelterwood System of regeneration have already been given and there follow some figures of costs for each. At one time it was hoped that some correlation would be found between the cost of an operation in a particular compartment and the type or density of the forest treated. This correlation has proved to be indefinite since it is complicated by the fact that almost every operation is done on a task basis for the labour gang, and by the great difficulty of assessing the average density of such vast areas of forest sufficiently accurately for use in costings.

In the paragraphs and tables which follow mention will be made of the way in which costs can be affected and examples of average, maximum and minimum costs of each operation will be given. The mean and extreme costs have not been calculated from the whole of the work done in Benin Division, but from samples taken at random. The samples range from approximately 8% to 33% of the total area under the Tropical Shelterwood System at the time of extraction from the records.

1. Demarcation. Original.

Cost: Maximum 10.8 chains per man-day (based on 1,504 chains)
Minimum 60.4 chains " " (based on 3,040 chains)
Average 38.2 chains " " (based on 63,116 chains)*

It may be argued that demarcation ought not to be included in a calculation of the cost of regeneration but it is felt by the writer that this charge must be shown, as the methods of labour organisation, control, record, etc., necessitate the sub-division of each compartment into strips. In a grid of square-mile compartments two miles of compartment boundary may be fairly apportioned to each square; internally there are normally three east-west 'quarter-lines' to be cut and thirty-one north-south grid lines to give the thirty-two 2½ chain-wide strips per mile. Thus, in a mile-square compartment thirty-six miles or 2,880 chains must be cut prior to the start of the Tropical Shelterwood System operations. This is equivalent to 4½ chains per acre or approximately ⅛ of a man-day per acre for original demarcation.

2. Demarcation. Recleaning.

Cost: Maximum 30.4 chains per man-day (based on 1,610 chains)
Minimum 135.0 chains " " (based on 2,560 chains)
Average 47.8 chains " " (based on 114,705 chains)

* The 'Maximum' and 'Minimum' costs are in fact 'Mean Maxima' and 'Mean Minima' in the sample. The figures in brackets show the amount of work from which these Means and the 'Average' costs have been calculated, while the brief statement after some of the averages is an attempt to show the deviation from the average, in a simple manner.

As stated above the average length of line per acre is $4\frac{1}{2}$ chains, and this is equivalent to one-tenth of a man-day per acre for recleaning.

3. <u>1st Climber Cutting</u>.

Cost: Maximum 1.61 man-days per acre (based on 102 acres)
Minimum 0.91 " " " (based on 638 acres)
Average 1.00 " " " (based on 4,362 acres)

4. <u>2nd Climber Cutting</u>.

Cost: Maximum 1.81 man-days per acre (based on 131 acres)
Minimum 0.66 " " " (based on 615 acres)
Average 0.91 " " " (based on 19,697 acres)

The cost of climber cutting is probably more closely connected to the state of the forest than any other operation, but the cost per acre, even here, cannot be used as an index of the density or type, except in the work of one labour gang. Climber-tangles (or "iloi" patches) occur in every compartment and the amount of marginal treatment of these, which is much slower and more expensive than cutting in closed high forest, depends almost entirely on the discretion of the individual overseer. General instructions and criticism of his work are given at intervals by the Forest Officer, Benin, or by an Assistant Conservator, but even these must be based on personal opinion and local impression and it seems likely, therefore, that while the basic cost for treatment of closed high forest can be made reasonably standard in all labour units, the amount of treatment in special areas, such as "iloi", will remain very variable and will depend largely on the opinions of the junior officer immediately in charge.

5. First Poisoning.

Cost: Maximum 1.30 man-days per acre (based on 391 acres)
Minimum 0.79 " " " (based on 640 acres)
Average 0.91 " " " (based on 29,446 acres)

6. Second Poisoning.

Cost: Maximum 1.50 man-days per acre (based on 34 acres)
Minimum 0.86 " " " (based on 1,475 acres)
Average 0.92 " " " (based on 14,846 acres)

With the poisoning operations tendencies in cost variations can be seen reasonably easily. It seems certain that a costly 1st Poisoning is usually followed by a cheap 2nd treatment, and vice versa. The following averages of samples from Sapoba Reserve and from Okomu Reserve show this, though it must be remembered that the two forests are not identical.

	Sapoba Reserve		Okomu Reserve	
	1st	2nd	1st	2nd
Man-days per acre	0.91	0.92	1.29	0.67
Poison per acre. lbs.	0.58	0.60	0.93	0.38
Trees poisoned per acre	108	89	188	44

At first sight the average cost per acre of 1st Poisoning in Okomu appears excessive, but the substantial reduction in cost in the second treatment brings the total cost only slightly above that for Sapoba. In Sapoba no reduction was possible in the second treatment. The detailed figures show that it is generally true that the higher the cost the greater is the amount of poison used and the larger is the number of treated trees per acre.

7. <u>Regeneration Counts</u>.

Cost: Maximum 0.29 man-days per acre (based on 75 acres)
Minimum 0.16 " " " (based on 1,012 acres)
Average 0.20 " " " (based on 9,528 acres)

8. <u>1st Cleaning</u>.

Cost: Maximum 1.10 man-days per acre (based on 963 acres)
Minimum 0.22 " " " (based on 733 acres)
Average 0.65 " " " (based on 13,667 acres)

9. <u>2nd Cleaning</u>.

Cost: Maximum 1.21 man-days per acre (based on 269 acres)
Minimum 0.43 " " " (based on 584 acres)
Average 0.58 " " " (based on 6,619 acres)

10. <u>3rd Cleaning</u>.

Cost: Maximum 1.63 man-days per acre (based on 742 acres)
Minimum 0.52 " " " (based on 806 acres)
Average 0.85 " " " (based on 6,792 acres)

The figures show that the average cost of 3rd Cleanings is higher than 1st Cleanings and this is to be expected since the weed growth has had longer time to develop and is growing in increasingly good light conditions. Also the number of seedlings shows a strong tendency to increase and this means that if the cleaning is selective and, in reality, limited to seedling assistance, there are more seedlings to be sought and cleared of creeper and weed growth. The following table summarises the average costs:-

Demarcation, Original	.13	man-days	per	acre
Demarcation, Recleaning	.10	"	"	"
1st Climber Cutting	1.00	"	"	"
2nd Climber Cutting	.91	"	"	"
1st Poisoning	.91	"	"	"
2nd Poisoning	.92	"	"	"
Regeneration Counts (two)	.40	"	"	"
1st Cleaning	.65	"	"	"
2nd Cleaning	.75	"	"	"
3rd Cleaning	.85	"	"	"
Total (to 3rd Cleaning only)	6.62	"	"	"

Before going on to consider the detailed results on a particular compartment which was managed under the Tropical

Shelterwood System it is necessary to stress one important point. The system to be applied was of necessity a "mechanical" one. Throughout the development and application period from 1943 to date there has been, by European forestry standards, a very severe shortage of supervision at all levels. The Forest Officer, Benin, in the years 1944 - 1949 was much of the time without a Senior Service assistant and in addition to developing the technique of the regeneration system he was responsible for the patrol and protection of over 1,500 square miles of forest, for staff, for revenue collection and for wages payment, almost all made personally with coins of denominations of one shilling and less to individual labourers, amounting to about £17,000 annually. Also there was the anxiety for four or five months of the year concerning the water supplies for the several hundred labourers and their families; water had to be transported by lorry for these people's every requirement and for the mixing of the Sodium arsenite poison. Artificial regeneration by the Taungya method over an annual planting area of 700 to 900 acres required organisation and supervision, and, in all the work, indifferent communcations had to be contended with. From this limited description it will be clear that senior supervision for the regeneration work was extremely limited.

With junior supervisory staff the position was undoubtedly better, but even so there was certainly no possibility either of stock-mapping compartments for regeneration before work started or of altering the technique to suit individual types of forest as they were found; the marking of trees for poisoning was quite impossible. The system was essentially mechanical with the trees to be poisoned decided by their species, not by silvicultural requirement, and cleaning specification laid down simply as a height from the ground. The work was new to the men, supervision was very scarce and if the work was to be done the application of the techniques as a kind of "drill" and the reduction of instructions to the simplest form were necessities.

The Survey of a Sample Compartment in Treated Forest.

The vast scale on which the Tropical Shelterwood System has been undertaken in Benin makes the assessment of success difficult and generalisations are very liable to be inaccurate. There is more likelihood of precision and truth in the findings if the study is confined to a single area of which the history and locality factors can be stated clearly. A survey, enabling this to be done, was made recently by the Nigerian Forest Department, and the writer, then a serving officer in that Department, had the fortune to be responsible for the work.

The primary objects of the survey were to assess the damage caused to regeneration by the exploitation of the mature timber and to study the survival and growth of seedlings in the post-exploitation period; this was to be achieved by repetitive enumeration and is not to be attempted here. The initial survey is, however, capable of yielding data to demonstrate the application of the regeneration system and what the writer feels are some of the fundamentals of the silviculture of this forest type.

The survey was carried out in Compartment 32, Usonigbe Forest Reserve (see Map 2) in the south-east of Benin Division. This compartment was chosen because it was fairly typical of the forest as a whole and because it had received all the recommended regeneration operations and was due for early exploitation by the timber firm.

Its typicality was borne out on the completion of the survey as there were found areas both rich and poor in seedbearers, areas both of 'clean' forest and, in contrast, forest with dense tangle or 'iloi'.

The area of the whole compartment is approximately 884 acres, but of this about 44 acres, on the extreme eastern boundary, lie in the shallow valley of the River Ehhimi. The forest on this small area was not subjected to regeneration operations and it was excluded from the survey. Thus the effective area is 840 acres, in one rectangular block, 60 gunter chains from north to south by 140 chains east to west.

The compartment was divided before the start of the survey into seven equal parts by lines running north-south 20 chains apart. (In a mile square compartment as are the majority in Benin, there are four such 20 chain-wide blocks of 160 acres in each compartment and each block is referred to as a Quarter; although there are seven 20 chain-wide areas in Compartment 32 the term 'Quarter' will still be used, as it is locally, for convenience). The layout of these Quarters can be clearly seen in Plan No. 1. The Quarters were numbered 1 to 7 from west to east.

The Quarters were divided into strips, each approximately $2\frac{1}{2}$ chains wide, by narrow paths (grid lines) running east-west. Owing to the extreme difficulty of obtaining accuracy with reasonable expenditure, the ideal was not attained and there were minor variations from the figure of $2\frac{1}{2}$ chains in the width of the strips. As the booking in the strips was closed every 4 chains, the compartment was, in effect, divided into plots, each of approximately one acre.

No 'surround' was demarcated, as might be done in a Sample Plot investigation. The compartment is sufficiently large to reduce marginal errors to a very low percentage. Also the forest to the north and to the south received precisely the same silvicultural treatment as Compartment 32; there was forest to the east, untreated certainly but sufficient to reduce marginal error still further; to the west was recently cleared forest, now farm land.

Compartment 32 has an elevation of approximately 150 feet above sea level, which is average for the region, and there are no large rises or falls in ground level. The fall to the bed of the River Ehdimi to the east is slight and is mainly outside the assessed area. Apart from this the ground is flat and level and there is no aspect. Owing to the very sandy nature of the soil the drainage is everywhere free; no streams flow through the area and the River Ehdimi contains water for only part of the rainy season, usually in July, August and September.

No direct evidence of farming was found but the nature of the vegetation in the eastern half of the compartment suggests that patches of farm land existed there within the last 50 years. Probably most or all of the compartment has at one time been farmed, but in the west this must have been at a very distant date. Some exploitation of the forest for timber appears to have taken place in the nineteen thirties, but this was limited to the removal of a few selected large trees of the Meliaceae.

During 1939 the compartment was properly demarcated. A valuation survey followed, to form an estimate of the mature timber available and the percentages of the area occupied by 'clean' forest, forest with some climbers, tangle, farm re-growth, etc. In the same year a start was made on an attempt, completely frustrated by the outbreak of war, to regenerate the forest by natural means; climber cutting was carried out, twice within the year, over much of the compartment. Nothing further was done and the climbers re-grew.

In 1942 seedlings were planted on the stump-sites of seven felled trees. These sites are now lost, the success is unknown, and the effect in an area of 840 acres can be discounted.

Work under the Tropical Shelterwood System began in September 1944. Demarcation of external boundaries, quarter-lines and grid lines was done and a First Climber Cutting was made.

The table below indicates the timing of the important operations.

Sept 1944	Demarcation of boundaries, quarter lines and grid lines
Oct - Nov 1944	First Climber Cutting
Dec 1944 - Mar 1945	First Poisoning
June - July 1945	Second Climber Cutting
August 1945	First Regeneration Count
Dec 1945	Second Poisoning
May - June 1946	First Cleaning
Sept 1946	Second Cleaning, with some re-poisoning
March - April 1947	Third Cleaning
Oct 1947	Fourth Cleaning
Nov 1947	Second Regeneration Count
Oct - Nov 1948	Fifth Cleaning

At the end of 1945 and the beginning of 1946, apparently as a result of a fear that the valuable Meliaceae trees were not regenerating sufficiently profusely, attempts were made to assist the natural regeneration by dibbling in seed on or near the grid lines. These efforts were only moderately successful and the small amount of work done, limited mainly to Khaya ivorensis, may be discounted; there is now no way of distinguishing between seedlings resulting from natural and artificial sowing.

To forestall the scheduled intensive timber exploitation in March 1950, a special cleaning was made in January of that year, and the survey of Compartment 32 was begun and completed in February 1950.

The object was to make as complete an assessment as possible of the economic trees, saplings and seedlings which might form the valuable portion of the crop for the next rotation. A count was made of regeneration in four classes:-

(a) Under 3 feet high

(b) Between 3 feet and 10 feet high

(c) Between 10 feet high and 1 foot girth B.H.

(d) Between 1 foot and 6 feet girth B.H.

This method varied from the routine Regeneration Counts only in the inclusion of class (d).

At the same time a simple map was built up, acre by acre, to show the distribution of tangle (see Plan No. 1.), and the mature seed-bearing trees, of the same species as were included in the regeneration count, were recorded acre by acre, girth being estimated to the nearest foot at breast height or above the highest buttress. The booking was closed every acre.

The species enumerated, both as regeneration and as seed-bearers, were the following:-

1. <u>Lovoa klaineana</u> L K

2. <u>Gossweilerodendron balsamiferum</u> G B

3. Entandrophragma angolense — E M

4. Entandrophragma cylindricum — E C

5. Entandrophragma candollei — E L

6. Guarea thompsonii — G T

7. Guarea cedrata — G C

8. Khaya ivorensis — K I

9. Chlorophora excelsa — C E

10. Antiaris africana — A A

11. Afzelia bipindensis — A B

12. Berlinia grandiflora — B G

13. Distemonanthus benthamianus — D B

14. Cylicodiscus gabunensis — C G

15. Brachystegia sp. — B L

16. Piptadenia africana — P A

17. Terminalia ivorensis — T I

18. Terminalia superba — T S

19. Triplochiton scleroxylon — T X

20. Sarcocephalus diderrichii — S D *

In this forest there are perhaps 200 species which have a tree habit, although some of these never grow beyond a small size. In the survey only twenty species were enumerated, and the selection was made on a basis of value as timber rather than frequency of occurrence, so that a species such as Chlorophora excelsa was

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* The abbreviations given here have been used in certain tables in this paper in order to avoid overcrowding; the initials are those commonly used by timber firms and by the Forest Department in Nigeria.

included although it is rare, while Annonidium mannii was excluded although it is very common. This manner of selection was probably unfortunate, certainly from the ecological view point, and it is obvious that the approach was subjective. It seems necessary to explain the reason for this. A survey of this type over an area of 840 acres is very expensive, both in the direct labour and in the interpretation of results, and funds would not permit a completely objective approach; the survey had to yield almost immediately figures to show the success or failure of the regeneration operations measured in terms of established seedlings per acre of species currently valuable. The results relate only to the species whose regeneration is truly sought in applying the Tropical Shelterwood System; other species are tolerated and later encouraged in that system as probably assisting in the reconstruction of the high forest structure after the great disturbance of exploitation.

It is a matter of simple arithmetic that with the enumeration closed for each acre of 840, counting twenty species in four classes, the expression of the regeneration alone involved 67,200 separate entries. The examination of all these results was found by the writer to be so cumbersome that this was abandoned and six plots, each of 20 acres, were chosen to demonstrate the tendencies and features which the survey as a whole reveals. In the pages which follow, and in the Plans which accompany this paper, reference will be made to the whole compartment usually to demonstrate broad tendencies and to the plots usually to discuss detailed results.

Mature Seedbearing Trees. (See Tables 2 to 8 on the pages following)

The enumeration of the mature trees in February 1950 revealed that there were approximately 1943 trees of the twenty ? selected species over 7 feet in girth breast height or above buttresses. The distribution of these was irregular; 1453 of them, or 75%, stood in Quarters 1, 2 and 3; 251, or 13%, stood in Quarter 4, and only 239, or 12%, stood in Quarters 5, 6 and 7. Another important fact is that in Quarters 1, 2 and 3 the extreme light demanding species, Terminalia ivorensis, Terminalia superba and Triplochiton scleroxylon total 101 trees, or 7% of the total, whereas the same species in Quarters 5, 6 and 7 total 133 trees, or 56% of the total. These two facts are obviously a direct result of the exploitation or, much more likely, the relatively recent farming in the eastern half of this compartment. The three species listed immediately above are, in this forest type and locality, typical of the vegetational seral stages after farming.

Table2.

Enumeration of Mature Trees: 20 Species:

Compartment 32: Usonigbe Forest Reserve: February 1950.

Quarter 1

Species	Basal Girth Classes in Feet 7 - 10	11 - 15	16 and over	Total
L K	6	1	-	7
G B	81	19	2	102
E M	23	3	1	27
E C	15	3	-	18
E L	1	1	-	2
G T	28	1	1	30
G C	20	1	-	21
K I	2	1	-	3
C E	3	-	-	3
A A	4	2	-	6
A B	1	-	-	1
B G	11	3	-	14
D B	32	1	-	33
C G	23	14	3	40
B L	3	-	-	3
P A	53	19	1	73
T I	21	5	-	26
T S	9	-	-	9
T X	4	-	-	4
S D	2	-	-	2
			Total	424

Table 3.

Quarter 2

Species	Basal Girth Classes in Feet 7 - 10	11 - 15	16 and over	Total
L K	2	-	1	3
G B	79	33	-	112
E M	27	-	-	27
E C	8	2	-	10
E L	5	-	-	5
G T	33	-	-	33
G C	21	2	-	23
K I	11	-	-	11
C E	1	-	-	1
A A	7	1	-	8
A B	-	-	-	-
B G	18	5	2	25
D B	38	2	-	40
C G	18	23	1	42
B L	18	3	-	21
P A	36	11	2	49
T I	10	5	-	15
T S	11	2	-	13
T X	5	1	-	6
S D	4	-	-	4
				Total 448

Table 4.

Quarter 3

Species	Basal Girth Classes in Feet 7 - 10	11 - 15	16 and over	Total
L K	2	-	-	2
G B	163	81	8	252
E M	30	1	-	31
E C	9	1	-	10
E L	-	1	-	1
G T	30	1	-	31
G C	31	4	1	36
K I	2	-	-	2
C E	2	-	-	2
A A	6	5	-	11
A B	-	-	-	-
B G	14	8	-	22
D B	47	5	1	53
C G	14	10	4	28
B L	12	4	-	16
P A	42	13	1	56
T I	17	1	-	18
T S	8	1	-	9
T X	1	-	-	1
S D	-	-	-	-
				Total 581

Table 5.

Quarter 4

Basal Girth Classes in Feet

Species	7 - 10	11 - 15	16 and over	Total
L K	-	-	-	-
G B	35	20	-	55
E M	13	1	-	14
E C	4	4	-	8
E L	1	1	-	2
G T	2	2	-	4
G C	6	1	-	7
K I	1	-	-	1
C E	2	-	-	2
A A	2	5	-	7
A B	1	-	-	1
B G	5	2	-	7
D B	9	1	1	11
C G	9	16	1	26
B L	1	5	3	9
P A	22	12	2	36
T I	31	1	-	32
T S	21	2	-	23
T X	4	1	-	5
S D	1	-	-	1

Total 251

Table 6.

Quarter 5

Species	Basal Girth Classes in Feet 7 - 10	11 - 15	16 and over	Total
L K	1	-	-	1
G B	5	2	-	7
E M	3	-	-	3
E C	1	-	-	1
E L	-	-	-	-
G T	-	1	-	1
G C	-	-	-	-
K I	1	-	-	1
C E	1	-	-	1
A A	-	1	1	2
A B	-	-	-	-
B G	-	-	-	-
D B	5	-	-	5
C G	1	1	-	2
B L	2	-	-	2
P A	6	2	-	8
T I	14	1	-	15
T S	20	-	-	20
T X	19	-	-	19
S D	1	-	-	1
				Total 89

Table 7.

Quarter 6

	Basal Girth Classes in Feet			
Species	7 - 10	11 - 15	16 and over	Total
L K	-	-	-	-
G B	1	-	-	1
E M	-	-	-	-
E C	-	-	-	-
E L	-	-	-	-
G T	-	-	-	-
G C	-	-	-	-
K I	-	-	-	-
C E	1	-	-	1
A A	-	-	-	-
A B	-	-	-	-
B G	4	-	-	4
D B	4	-	-	4
C G	1	-	-	1
B L	5	3	-	8
P A	5	1	-	6
T I	5	-	-	5
T S	9	1	-	10
T X	10	1	-	11
S D	-	-	-	-
				Total 51

Table 8.

Quarter 7

	Basal Girth Classes in Feet			
Species	7 - 10	11 - 15	16 and over	Total
L K	-	-	-	-
G B	8	2	1	11
E M	1	-	-	1
E C	-	-	-	-
E L	-	-	-	-
G T	-	-	-	-
G C	-	-	-	-
K I	1	-	-	1
C E	2	-	-	2
A A	-	-	-	-
A B	-	-	-	-
B G	-	-	-	-
D B	3	-	-	3
C G	4	1	-	5
B L	6	4	-	10
P A	10	2	-	12
T I	8	-	-	8
T S	31	1	-	32
T X	11	2	-	13
S D	1	-	-	1
				Total 99

It has already been mentioned that this compartment was 'creamed' of its largest stems in the nineteen thirties and this probably accounts for the relative absence of very large trees. Nevertheless, the stocking of Gossweilerodendron balsamiferum and the species of the family Meliaceae (the first eight species listed in the tables) in the western half of the compartment is excellent. Reference to the distribution of seedbearers will be made in the detailed consideration of individual species.

Tangle Vegetation.

Over a considerable proportion of the compartment tangle of varying density was found to exist. An indication of the distribution of tangle vegetation is given on Plan No. 1. In parts it consisted of tall monocotyledonous weeds, such as Aframomum species, with an interlacing of fine herbaceous climbers or creepers which hardly constitutes tangle. Elsewhere it consisted of an almost impenetrable mass of Calamus and Oncocalamus species from ground level up to 15 feet or more. Acacia pennata and Acacia ataxacantha were locally important members of the tangle patches, especially in the eastern half of the compartment.

In Quarter 1, at the western end of the compartment, the parts marked green on Plan No. 1. were of the least obnoxious type, little more than patches of herbaceous weeds which had not been cut; they did not constitute true tangle vegetation and were not a deterrent to tree seedlings which could grow through the weeds.

In the northern half of Quarter 2 conditions were similar to those described in the preceding paragraph, but in the southern half there was an area of bad tangle which (although not of the worst Calamus - Oncocalamus type found near the eastern boundary of the compartment) formed a blanket over the ground and had an important effect on the regeneration. The tangle had been cut back in some areas, which reduced its apparent area at the time of the survey but its presence during most of the regeneration period had been effective in reducing regeneration drastically.

Quarter 3 was found to be virtually free of tangle.

In Quarter 4 the tangle was unimportant in the north, and in the south it was patchy but increasing in density as one went south, reaching greatest severity on the extreme southern boundary.

In Quarter 5 the north-eastern corner, and an irregular strip a few chains from the northern boundary were tangle covered. In the south were patches of varying density.

Quarter 6 was found to be irregularly covered with patches of relatively severe tangle.

In Quarter 7 the tangle was severe, especially in the south. Almost all semblance of forest structure was lacking over some areas several acres in extent, with the palm climbers and Acacia forming a dense mass in which movement was impossible except on cut lines. Near the eastern boundary and about fifteen chains from the northern boundary was an area in which timber trees and a good forest structure remained. This area was free of climbers.

It should be noticed that in the eastern half of the compartment the existence of tangle coincided with a paucity of seedbearing trees; the removal of the latter created the conditions for the growth of climber tangle near or on the ground. In the western half, however, a major area of tangle was found in forest which was relatively rich in seedbearing trees.

<u>Regeneration in Relation to the Distribution of Seedbearers and Tangle</u>.

(a) <u>Gossweilerodendron balsamiferum</u>. See Plan No. 3. This species was the most common found, in both seedbearers and regeneration. The mature trees were present in the greatest concentration in the northern half of Quarter 3 where they averaged 2.7 trees per acre over 7' basal girth. The regeneration was most common in the southern half of Quarter 1. As this species has a samara-like fruit (although a member of the family Caesalpiniaceae) at least limited distribution by wind is possible and as the fruit is ripe at the period of most violent wind storms in March, dispersal is probably fairly wide. In spite of this fact and of the existence of 39 seedbearers well distributed on the 60 acres, the southern half of Quarter 2 formed an island of low density of regeneration, bounded on one side by an area with a seedling stocking over 70 per acre and on two by areas with more than 150 seedlings per acre.

The reason for the small areas of low stocking in the north of Quarter 3 is not known by the writer, but it seems significant that on the southern boundary of Quarter 4 the area with fewer than 25 seedlings per acre coincides with the only severe tangle in this quarter.

Apart from the small well-stocked area in the south-east, the pattern of the seedling distribution closely follows the distribution of tangle in Quarter 7: the low area in the extreme north: the high density in the tangle-free area a furlong and a half from the northern boundary, coinciding with good-structure forest containing seedbearers: the low density areas of the south coinciding with climber tangle.

In brief, the wind dispersal of the fruit and the abundance and regularity in fruiting reduces, in theory, the need for seedbearers in the immediate vicinity to obtain regeneration. This is borne out, in practice, by the existence of high density stocking of seedlings remote from seedbearers; e.g. in Quarter 5, a density of 70 seedlings per acre more than 220 yards from the nearest recorded seedbearer. The seedling density certainly tends to drop sharply in tangle areas and this is shown most clearly in Quarter 2, south, although seedbearers are well distributed there.

From personal observations it is clear that regeneration of this species can exist in shade and that it is most common in areas where the forest structure is best displayed (i.e. shrub layer, middle storey, upper storey, emergents and, incidentally, no ground tangle.) The development of the individual tree has long been, and remains, an enigma; the seedling has the form of a gooseberry bush yet a misshapen mature tree is a great rarity; the bole is without buttresses or basal thickening, rising cylindrically from the ground and frequently straight, unbranched and with extremely little taper to 80 feet.

(b) Lovoa klaineana. See Plan No. 2. As with mature trees this species is not common; only 13 were recorded in the whole compartment. Over most of the area surveyed, however, more than 25 seedlings per acre were found, and in the south of Quarter 1 and the northern half of Quarter 2 more than 70 per acre.

As was found with Gossweilerodendron the southern half of Quarter 2 has a low stocking of seedlings. The severe tangle areas on the southern boundary of Quarters 4 and 5 and in Quarter 7 are also low stocking areas. There is again a low stocking area in the centre, and in the north, of Quarter 3, for which no adequate reason is known.

The seed of Lovoa klaineana is light, winged and easily wind dispersed so that the fairly large total number of seedlings from the few seedbearers is not surprising. The seeds germinate in enormous numbers following a heavy fruiting and in the early weeks the seedlings are shade-tolerant; this tolerance is gradually lost, however, and at an age of four or five months the plants are decided light demanders, so that, unless light is available they will die. The analysis of the regeneration present in the selected plots (see pages 87- 92) is a measure of the success achieved in the Tropical Shelterwood System by maintaining seedlings of this species and permitting their development. It is an excellent species for use as a key to decide the adequacy of canopy opening.

(c) _Guarea thompsonii_. See Plan No. 4. With the form of fruit and seed and the frequent failure of dehiscence to occur on the tree it is logical to expect the regeneration to be much more closely associated with the distribution of the seedbearers than was found to be the case with _Gossweilerodendron_ and _Lovoa_. As the seeds are attractive to animals, dispersal is probably dependent to a large extent on mammals, particularly rodents.

As the area of low seedling density, coloured light green on the plan, covers both clean forest and tangle any correlation between seedling distribution and the absence of tangle is rather obscured, but it is true that none of the areas of higher seedling density coincides with a dense tangle, except for very small patches.

In the figures for regeneration in the selected Plot No. 1. it is noticeable that for this species 60% of the seedlings are above 10 feet high, and more than half of these are above 1 foot in girth. This species is a very slow grower and these figures indicate the probability that many of the seedlings were present as advance growth before the start of regeneration work. The seedlings can exist in very low light intensity and seem even to prefer or demand these shade conditions early in life.

(d) Guarea cedrata. Although not present in great numbers, the seedbearers of this species are well distributed in the western half of the compartment. The seed is not adapted for wind dispersal but the regeneration is well distributed in Quarters 1 to 4 except in two areas. The southern half of Quarter 2 again shows as a large island of lower density of stocking, coinciding with the low areas already noted for Gossweilerodendron and Lovoa, and with the area of tangle. The much smaller serpentine area of low density in central Quarter 3 recurs.. In Quarters 5, 6 and 7 the complete absence of seedbearers and the presence of tangle reduces the number of seedlings severely. The very low stocking in the dense tangle on the southern Quarter 4 boundary and in the south of Quarter 7 are significant.

Like Guarea thompsonii this species can exist in shade, especially in youth.

(e) Khaya ivorensis. See Plan No. 8. This is a most desirable species to obtain as regeneration because it has been for many years, and probably always will be, regarded as an extremely valuable timber. Owing to the severe attacks on the leading shoot by borers when the sapling is growing in full light, it is definitely quite unsuitable for ordinary plantation techniques and future supplies of timber will almost certainly depend entirely on natural regeneration. The seed is winged and wind dispersal is generally excellent. For the production of straight, well-grown saplings some top-shade is essential, but although the seedling can tolerate heavy shade in youth the shade must be gradually lightened. It seems clear that conditions approximating to the optimum for the regeneration of Khaya can be created by the Tropical Shelterwood System provided that multi-storeyed structure is well developed in the forest; this permits the removal by cutting or poisoning of the shrub-layer and middle storey to leave the lighter canopied upper storey trees as high shade, at least during the regeneration period. Young advance growth and seedlings germinated at the same time of the 1st Climber Cutting are given the desirable slow increase in available light owing to the protracted death of poisoned trees.

Plan No. 8. shows again the lack of seedlings in the southern Quarter 2 tangle area and in the eastern part of the compartment. The Quarter 4 southern boundary area also shows paucity of seedlings in the severe tangle. It is generally true that areas with the best stocking of seedlings are tangle-free and where ~~the~~ many seedlings and tangle are coincident the tangle is usually the light herbaceous type above which there is some shade.

(f) Entandrophragma angolense. See Plan No. 7. With a moderately large number of seedbearers well distributed in the western half of the compartment, the regeneration of this species appears rather disappointing in numbers. The seed is winged and well adapted for wind dispersal.

The southern half of Quarter 2 again shows as a very light stocking of seedlings, but the effect is less striking as the whole compartment to the east is little better. Although the seedbearers are most frequent in the southern parts of Quarters 2, 3 and 4, the regeneration was found most profuse in Quarter 1 and the northern parts of 2 and 3.

(g) Entandrophragma cylindricum. See Plan No. 9. With forty-six well distributed seedbearers in Quarters 1 to 4 the regeneration of this species is disappointing. The seed is winged and much is wind-dispersed so that even with the moderate number of mature trees more seedlings might have been expected. The reason probably lies in the seedlings' light requirements; in very early life they can stand shade but very soon nearly full light seems necessary for their development, and they are then fast growing. It may well be that the light admitted early in the application of the Shelterwood System (and the 1st Poisoning must have been rather cautious) was insufficient for regeneration of this species. Support for this may lie in the presence of two blocks of relatively good stocking in Quarter 6, where the forest structure was rather poorly developed and the poisoning removed relatively more of the shade than further west.

(h) Entandrophragma candollei. See Plan No. 12. Relatively little can be learned from a study of the figures. Seedbearers are few in the compartment, as they are almost everywhere in Benin Division, for this species is not common. Regeneration is poor throughout the forest and that is also true in Compartment 32. The slightly better stocking appears to be only in tangle-free forest and generally in the vicinity of the seedbearers.

(i) Sarcocephalus diderrichii. See Plan No. 11. Seedbearers in the compartment are few and regeneration is everywhere scarce. The minute seed is embedded in the globular flesh fruit which is prized as food by mammals and insects. The seedlings are intense light demanders and under shade are badly attacked by shoot-boring Lepidoptera larvae. Natural regeneration in Benin is everywhere uncommon and its scarcity here is not surprising. The species is used very extensively in Benin for artificial regeneration for which it is ideal.

(j) Chlorophora excelsa. See Plan No. 13. Seed-bearers and regeneration are scarce throughout the compartment; the species is not a typical constituent in this forest type, belonging truly to the dry mixed deciduous forest to the north and north-west of Benin. Conditions favouring the regeneration are particularly hard to obtain; the seedlings are light demanding, yet in the light they become very heavily, and often fatally, attacked by the gall-forming insect, Phytolyma lata: with increased shade there is progressively decreased insect attack and decreased vigour to the state of immunity and complete suppression. In the surveyed area Chlorophora is not an important constituent of the regeneration, although the figures suggest that in the next rotation it will maintain its presence.

(k) Berlinia grandiflora. See Plan No. 15. There is a good distribution of seedbearers of this leguminous species in Quarters 2 and 3. Among smaller poorly stocked areas the southern half of Quarter 2, the southern boundary strip of Quarter 4 and Quarter 7 (except for the clean-forest area one to two furlongs from the northern edge) are prominent. The regeneration is surprisingly well distributed and dense for a species with a large seed. The species has light requirements very similar to Khaya and this is reflected in the distribution maps of the regeneration. For this species also the remarks concerning the apparent inability of seedlings to flourish in tangle in spite of the immediate proximity of seedbearers remain true.

(l) Piptadenia africana. See Plan No. 16. Like Berlinia this is a member of the Leguminosae; the seed is flat with a surrounding membranous wing. The distribution of seedbearers is good throughout Quarters 1 to 4, but the regeneration distribution does not follow this pattern and the southern half of Quarter 2 and the southern boundary strip of Quarter 4 are again conspicuous as areas of poor stocking; the regeneration is most dense in the clean forest. The smaller concentration of seedbearers in Quarter 7 does not seem to have produced a proportionate number of seedlings except in the patch of clean forest in the northern half. The distribution of seedlings appears to depend on the cleanliness of the forest rather than on the availability or proximity of seedbearers.

(m) Triplochiton scleroxylon. See Plan No. 10

(n) Terminalia ivorensis. See Plan No. 5

(c) <u>Terminalia superba</u>. See Plan No. 14.

The three species listed above are all intense light demanders. The distribution maps reveal no connection between concentration of seedlings and cleanliness of forest, but it is quite clear that even large numbers of seedbearers in considerable concentration failed to produce appreciable regeneration. It is quite clear that for these species, which require full light for their regeneration, the Tropical Shelterwood System does not produce conditions approximating to the open, post-farming conditions in which they thrive. This is no criticism of the System for there are many square miles of abandoned farm land in which these species can thrive and which they can relatively quickly reafforest, but there is a limited area in which the <u>Meliaceae</u> timber trees and their associates can be maintained, for the latter are not pioneer species. On the contrary, the regeneration of Meliaceous forest by <u>Triplochiton</u> and <u>Terminalia spp</u>. would be an indication of the failure of the Tropical Shelterwood System.

Selected Regeneration Plots

Compartment 32: Usonigbe Forest Reserve

Results and Conclusions

Six plots, each of twenty acres and each measuring twenty chains east-west by ten chains north-south, have been selected to demonstrate the conclusions reached. The positions of the plots are shown on Plan No. 1 . The figures for the regeneration, by size classes and by species, and for the seedbearers, are given in Tables 9 to 14 on pages 87 to 92 .

Plot 1 was in Quarter 1 and in tangle-free forest with a well-developed structure; there was an upper storey to give light top shade when the heavy shade casting trees of the middle canopy were removed by poisoning. Regeneration was excellent, 18,517 seedlings and poles being enumerated. Of this total 45.25% were of species of the Meliaceae and 17.76% were Gossweilerodendron balsamiferum, while the intense light demanding Triplochiton, Terminalia and Sarcocephalus spp. made up less than 0.5%. Seedbearing trees were numerous in the vicinity and there were 71 of all the listed species in the plot. In brief, there were numerous seedbearers in clean forest and regeneration of the most desired species was very abundant.

Plot 3 was in Quarter 3, also in tangle-free forest with a well-developed structure. Regeneration was slightly less plentiful than in Plot 1, totalling 14,031 seedlings and poles of the twenty species. The build-up of this was similar to that in Plot 1, 39.58% of Meliaceous species and 16.75% of Gossweilerodendron. Again seedbearers were abundant, totalling 118 of the twenty species.

Plot 4 in the southern half of Quarter 3 confirms the results for Plots 1 and 3. The forest was clear of tangle and seedbearers were plentiful, totalling 83. Regeneration was excellent; 13,025 seedlings and poles were found, of which 45.30% were of the Meliaceous species and 18.77% were Gossweilerodendron.

Conditions of soil, vegetation and incidence of seedbearers in Plots 1, 3 and 4 were very similar, and very similar figures for the total number of seedlings and poles were obtained in the three, together with remarkably regular percentages of the constituent species.

Plot 5, in Quarter 5, demonstrates the results obtainable in tangle-free forest similar to Plots 3 and 4, except that is in an area with few seedbearers of the twenty surveyed species. In the plot were only two seedbearers, both of relatively unimportant species for this forest. In spite of this the total number of seedlings and poles showed only a slight drop to 11,575, the Meliaceae making up 44.46% of this total and Gossweilerodendron

12.32%. These figures show the ability of this forest to regenerate freely in tangle-free areas although seedbearers were not nearby or standing on the area.

In Plot 2 in the southern half of Quarter 2, conditions were similar to Plots 1, 3 and 4 in the presence of adequate seedbearers, but conditions were dissimilar in the presence of tangle. Fifty-two seedbearers, of fourteen species, were recorded, yet the recorded number of seedlings and poles dropped to 6,409.

In Plot 6 in the southern part of Quarter 7, conditions were worse than in Plot 2. The area was covered with tangle and seedbearers were few, only 18 being recorded and these of only two species, Triplochiton scleroxylon and Terminalia superba, which together produced only 3.85% of the reduced regeneration total.

In these six plots soil, climate, aspect and drainage ? ? may be taken approximately as constants. Silvicultural treatment was constant in so far as the existing vegetation made this possible; it is clearly impossible to remove an already non-existent middle canopy and climber-cutting in the densest tangle is a practical impossibility; ~~silvilcultural~~ silvicultural treatment in Plots 1, 3, 4 and 5 was similar. The variable of animal populations probably exists but with weed growth cut back leaving the seedlings clear and obvious in the tangle-free areas, it may well be that animals destroy relatively more seedlings in the clean forest than in the tangle.

The two principal variables which appear to remain are those of occurrence of seedbearers and the presence or absence of tangle. With these two variable conditions the plots seem to fall into four classes:-

(a) Plots 1, 3 and 4: ample seedbearers: no tangle

(b) Plot 5: very few seedbearers: no tangle

(c) Plot 2: ample seedbearers: tangle present

(d) Plot 6: very few seedbearers: tangle present

In both (a) and (b) regeneration was found to be very plentiful while in (c) regeneration was not plentiful. From this it seems clear that the immediate presence of seedbearers is neither a necessity for, nor a guarantee of, the establishment of plentiful regeneration of the species surveyed. ?

In classes (a) and (c) there were adequate seedbearers but in (c) alone was there tangle. In (c), Plot 2, regeneration was most scarce; the presence of tangle appears to reduce drastically the regeneration obtained, and this is confirmed in Plot 6, (d) above, where lack of local seedbearers and tangle together reduced the regeneration even more.

It might be argued that another variable was the human factor; with the increased difficulty of enumeration in tangle the number of seedlings existing but not found might be considerable. While some reduction of totals owing to seedlings being uncounted in climber tangle undoubtedly occurred, this factor cannot have been vitally important for the following reason. Of the 60 acres, approximately, which made up the low stocking area in the southern half of Quarter 2, 50% had been sufficiently cleared of tangle in the pre-survey cleanings to be marked as a non-tangle area, although it was quite obvious that tangle had existed there recently. The clearing had been done well enough to permit as careful and complete working there as in the neighbouring forest in Quarters 1 and 3. In spite of this the totals of seedlings found were similar and in some cases slightly lower than those recorded in the remaining tangle in Quarter 2.

Quite obviously seedbearers are necessary for the obtaining of adequate regeneration but their immediate presence on an area is not a necessity. Much more important is the form of the forest, the presence of a good forest structure and the absence of tangle. The Tropical Shelterwood System appears to be well suited to the regeneration of the economically important forest characterised by _Khaya ivorensis_, _Guarea spp._, _Entandrophragma spp._, _Lovoa klaineana_, _Gossweilerodendron balsamiferum_, etc., provided that there is a storeyed structure and no serious tangle. It appears unsuitable for regeneration of tangled, unstoreyed forest, even if there are adequate seed-bearers, because the vital operations cannot be executed. A corollary is that every care must be exercised to prevent the encroachment of tangle on previously clean forest and strenuous efforts must be made to preserve the structure of the forest, so far as this is compatible with the necessary silvicultural opening of the canopy. After exploitation the most vital consideration in the early years of the next rotation should be the maintenance of the forest structure, the best and cheapest weapon with which to combat the tangle.

Table 9

Regeneration Plot No. 1

Species	LK	GB	EM	EC	EL	GT	GC	KI	CE	AA	AB	BG	DB	CG	BL	PA	TI	TS	TX	SD	TOTALS.
Regeneration Below 3' high	551	1252	250	46	57	158	1168	501	7	57	220	813	91	262	43	877	3	8	-	3	6367
3' to 10' high	215	399	189	76	9	103	287	231	37	80	170	240	134	208	65	498	48	3	2	14	3008
10' high to 1' g.	560	1113	346	153	16	189	1175	536	21	35	96	687	67	180	-	895	2	1	-	2	6074
1' to 6' girth	227	525	172	96	40	217	602	211	-	6	131	273	52	62	12	440	-	2	-	-	3068
Totals	1553	3289	957	371	122	667	3232	1479	65	178	617	2013	344	712	120	2710	53	14	2	19	18,517
% of Grand Total	8.38	17.76	5.17	2.00	0.66	3.60	17.45	7.99	0.35	0.96	3.33	10.87	1.86	3.85	0.65	14.64	0.29	0.08	0.01	0.10	100%
Mature Trees	-	13	4	3	-	6	4	-	-	-	-	8	5	10	-	17	1	-	-	-	71

Table 10

Regeneration Plot No. 2

Species	LK	GB	EM	EC	EL	GT	GC	KI	CE	AA	AB	BG	DB	CG	BL	PA	TI	TS	TX	SD	TOTALS
Regeneration																					
Below 3' high	41	318	48	4	6	32	109	53	14	40	24	106	14	48	10	69	5	4	5	-	950
3' to 10' high	230	515	209	66	14	259	414	377	58	169	315	425	158	289	50	496	21	70	5	-	4140
10' high to 1' g.	86	51	68	5	4	38	327	101	10	15	33	81	21	19	1	58	1	-	-	2	921
1' to 6' girth	31	67	28	9	1	26	127	11	1	10	1	14	18	4	2	44	2	-	-	2	398
Totals	388	951	353	84	25	355	977	542	83	234	373	626	211	360	63	667	29	74	10	4	6409
% of Grand Total	6·05	14·84	5·51	1·31	0·39	5·54	15·24	8·46	1·30	3·65	5·82	9·77	3·29	5·62	0·98	10·41	0·45	1·15	0·15	0·06	100%
Mature Trees	-	4	2	-	-	6	5	1	-	1	-	2	5	8	1	11	2	2	2	-	52

Table 11 Regeneration Plot No 3

Species	LK	GB	EM	EC	EL	GT	GC	KI	CE	AA	AB	BG	DB	CG	BL	PA	TI	TS	TX	SD	TOTALS
Regeneration																					
Below 3' high	261	863	158	15	35	97	639	364	3	39	243	502	36	269	181	457	-	1	-	-	4153
3' to 10' high	119	549	243	63	95	233	425	328	26	89	265	406	104	411	39	678	-	29	-	-	4102
10' high to 1' g.	245	662	211	64	82	90	818	371	6	64	157	494	24	257	162	531	1	-	-	2	4241
1' to 6' girth	39	276	22	14	36	-	359	128	3	9	72	209	16	47	61	243	1	-	-	-	1535
Totals	664	2350	634	156	248	420	2241	1191	38	201	737	1611	180	974	443	1909	2	30	-	2	14,031
% of Grand Total	4·73	16·75	4·52	1·11	1·77	2·99	15·97	8·49	0·27	1·43	5·25	11·48	1·28	6·94	3·16	13·61	0·01	0·21	-	0·01	100%
Mature Trees	-	61	4	2	-	6	7	1	-	4	-	3	12	2	5	9	1	1	-	-	118

Table 12

Regeneration Plot No. 4

Species	LK	GB	EM	EC	EL	GT	GC	KI	CE	AA	AB	BG	DB	CG	BL	PA	TI	TS	TX	SD	TOTALS.
Regeneration																					
Below 3' high	361	857	150	59	-	72	758	405	6	23	164	473	2	99	-	382	-	-	-	-	3811
3' to 10' high	265	559	317	140	46	227	397	231	6	83	276	278	84	246	6	487	-	3	-	-	3651
10' high to 1' g.	352	712	132	49	5	23	765	378	-	2	141	503	-	239	-	531	-	-	-	-	3832
1' to 6' girth	176	317	48	24	10	17	342	124	5	1	111	190	27	66	-	273	-	-	-	-	1731
Totals	1154	2445	647	272	61	339	2262	1138	17	109	692	1444	113	650	6	1673	-	3	-	-	13,025
% of Grand Total	8·86	18·77	4·97	2·09	0·47	2·60	17·37	8·74	0·13	0·84	5·31	11·09	0·87	4·99	0·05	12·84	-	0·02	-	-	100%
Mature Trees	-	23	11	2	-	5	6	-	-	1	-	1	9	10	-	8	6	1	-	-	83

Table 13

Regeneration Plot No 5

Species	LK	GB	EM	EC	EL	GT	GC	KI	CE	AA	AB	BG	DB	CG	BL	PA	TI	TS	TX	SD	TOTALS
Regeneration																					
Below 3' high	469	591	244	72	46	72	488	544	36	81	176	600	40	101	41	727	11	2	-	-	4341
3' to 10' high	70	217	120	59	86	21	235	331	10	56	141	182	50	91	27	392	8	8	-	1	2105
10' high to 1' g.	346	521	153	141	30	101	608	664	70	58	156	534	67	109	71	558	9	14	-	10	4220
1' to 6' girth	28	97	23	26	9	38	89	113	39	4	39	198	22	12	45	105	15	7	-	-	909
Totals	913	1426	540	298	171	232	1340	1652	155	199	512	1514	179	313	184	1782	43	31	-	11	11,575
% of Grand Total	7·89	12·32	4·67	2·57	1·48	2·00	11·58	14·27	1·34	1·72	4·42	13·08	1·55	2·70	1·59	15·40	0·37	0·28	-	0·10	100 %
Mature Trees	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	2

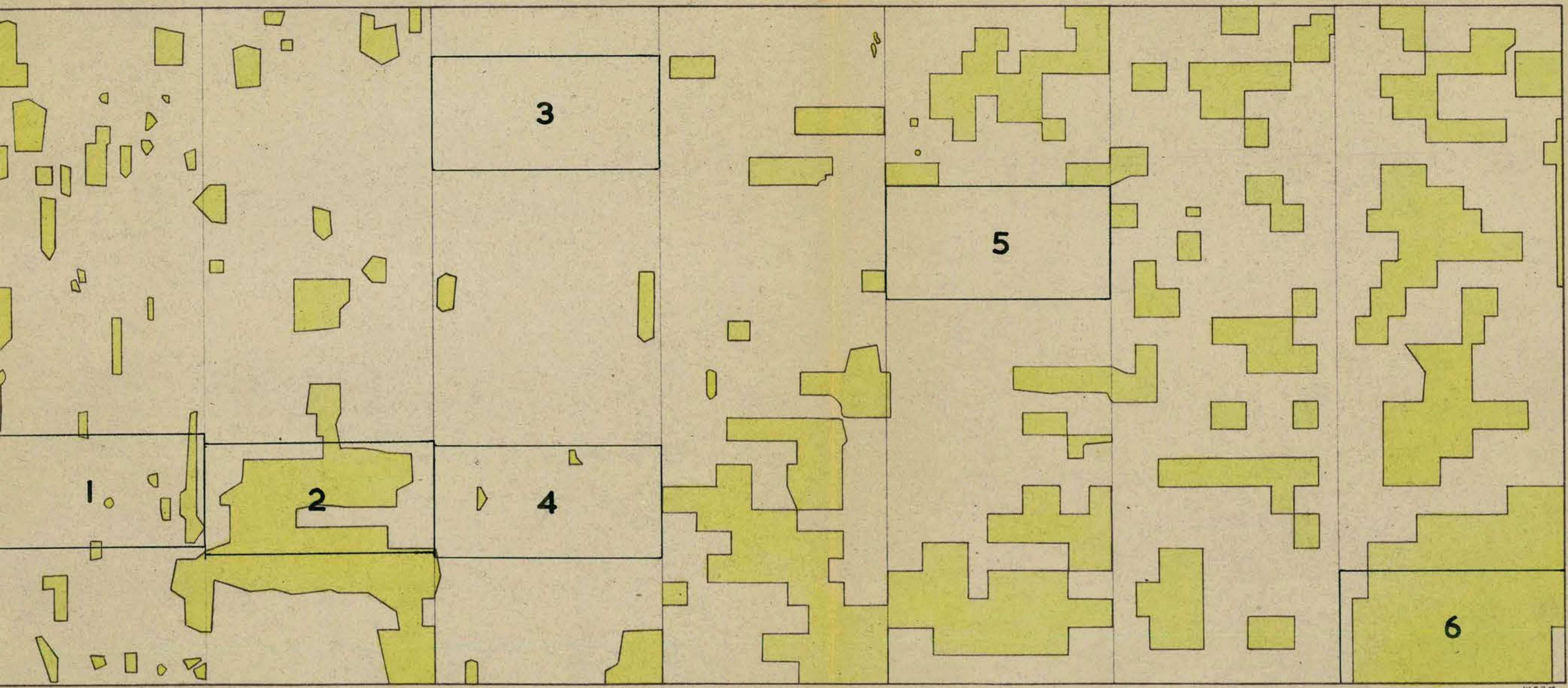
Table 14 Regeneration Plot No. 6

Species	LK	GB	EM	EC	EL	GT	GC	KI	CE	AA	AB	BG	DB	CG	BL	PA	TI	TS	TX	SD	TOTALS.
Regeneration																					
Below 3' high	6	219	24	13	-	17	104	7	-	9	2	35	1	8	-	12	-	1	-	-	458
3' to 10' high	122	526	88	35	-	21	139	85	-	61	92	172	50	42	-	200	-	25	-	-	1658
10' high to 1' g.	22	21	22	1	-	7	10	11	3	9	23	47	10	10	-	13	1	8	2	-	220
1' to 6' girth	1	13	4	-	1	1	3	2	2	1	3	15	11	4	-	7	-	54	5	-	127
Totals	151	779	138	49	1	46	256	105	5	80	120	269	72	64	-	232	1	88	7	-	2463
% of Grand Total	6·13	31·63	5·60	1·99	0·04	1·87	10·39	4·26	0·20	3·25	4·87	10·92	2·92	2·60	-	9·42	0·04	3·57	0·28	-	100%
Mature Trees	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	11	-	18

PLAN No I

DISTRIBUTION OF TANGLE VEGETATION

COMPARTMENT 32 - USONIGBE FOREST RESERVE



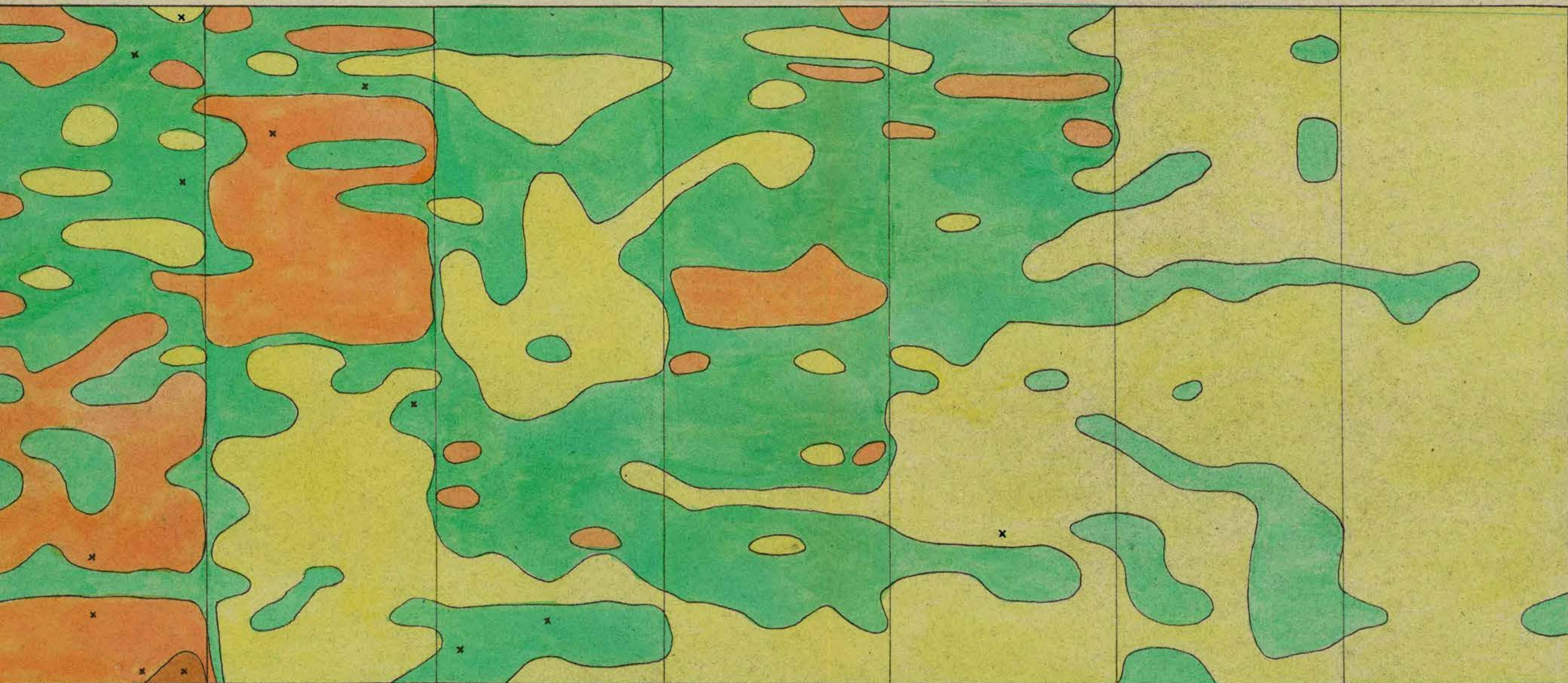
SCALE - 1 : 7,920 or 8 INCHES TO 1 STATUTE MILE

TANGLE ~ GREEN
CLEAN FOREST ~ UNCOLOURED

PLAN No 2

DISTRIBUTION OF LOVOA KLAINEANA

COMPARTMENT 32 - USONIGBE FOREST RESERVE



W.E.S.M.

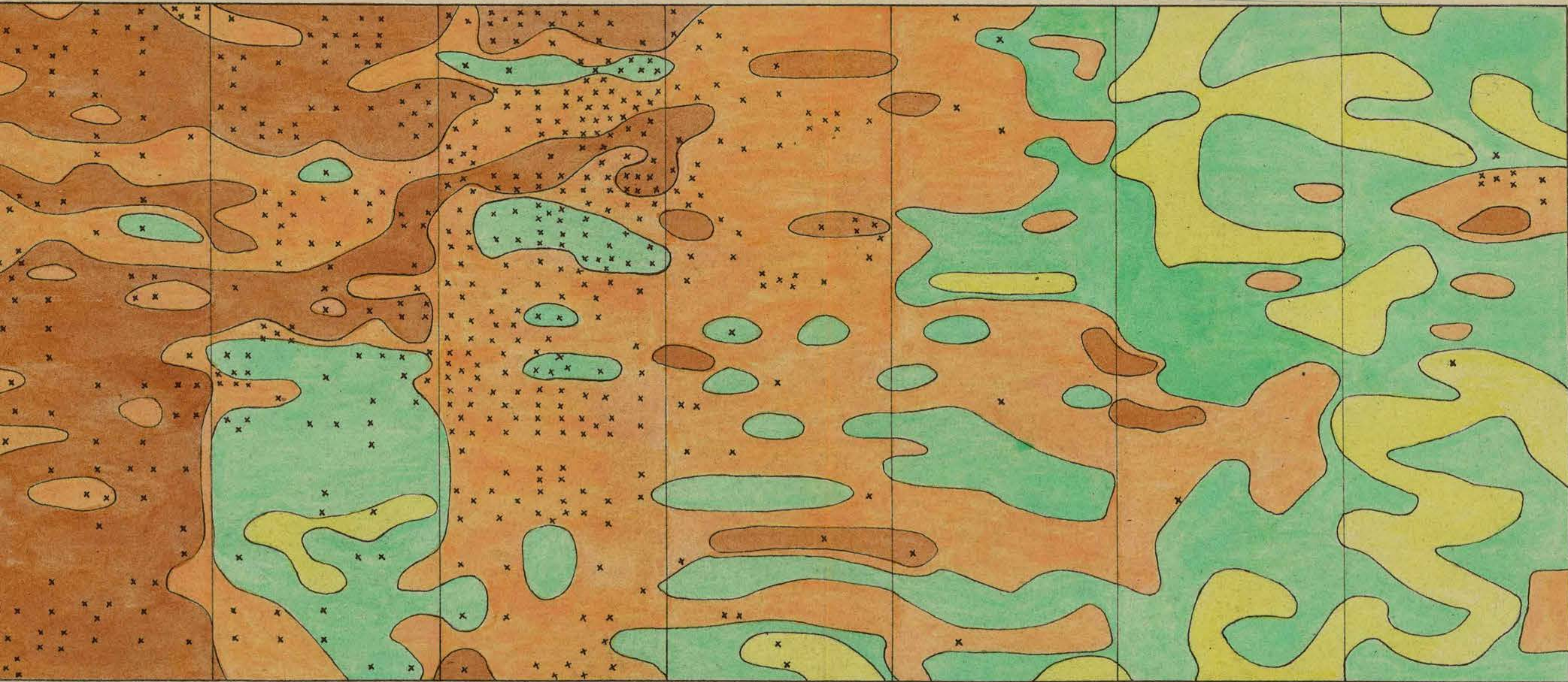
SCALE - 1 : 7,920 or 8 INCHES TO 1 STATUTE MILE

SEEDLINGS and POLES

0 to 25 per acre	(yellow)
25 to 70 " "	(green)
70 to 150 " "	(orange)
150 and more " "	(brown)

PLAN No 3 DISTRIBUTION OF GOSSWEILERODENDRON BALSAMIFERUM

COMPARTMENT 32 - USONIGBE FOREST RESERVE



W.E.S.M.

SCALE - 1 : 7,920 OR 8 INCHES TO 1 STATUTE MILE

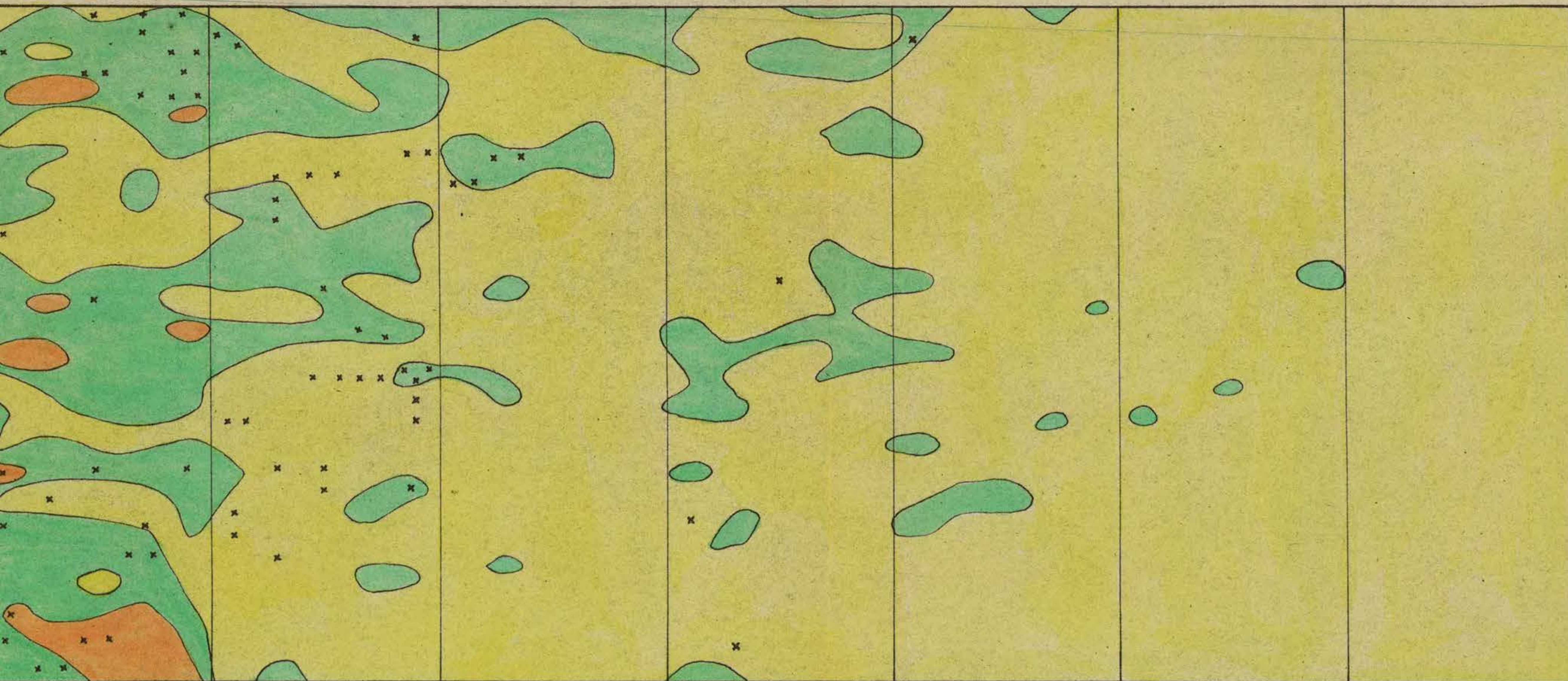
SEEDLINGS AND POLES

Under 25 per acre
25 to 70 " "
70 to 150 " "
Over 150 " "

PLAN No 4

DISTRIBUTION OF GUAREA THOMPSONII

COMPARTMENT 32 – USONIGBE FOREST RESERVE



W.E.S.M.

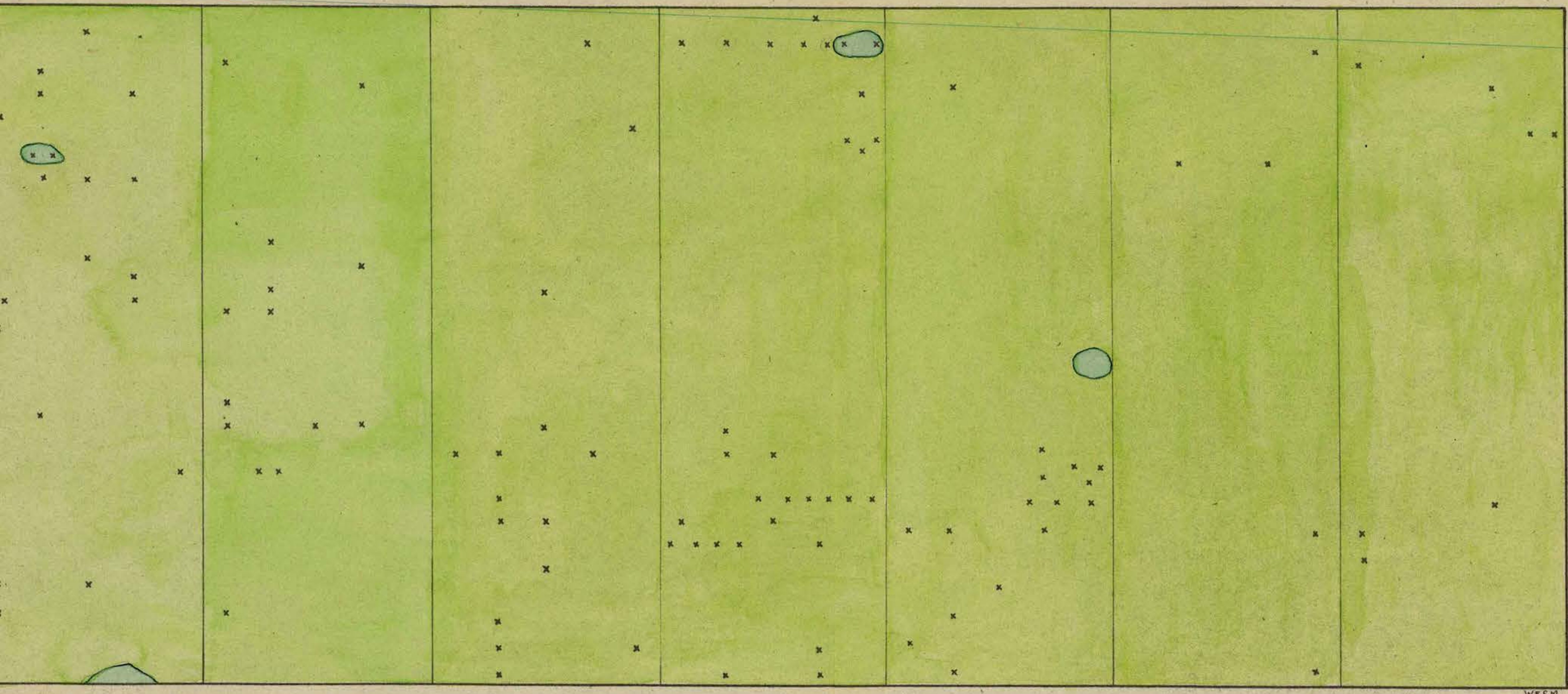
SCALE – 1 : 7,920 or 8 INCHES TO 1 STATUTE MILE

SEEDLINGS AND POLES
- UNDER 25 PER ACRE
- 25 TO 70 " "
- 70 TO 150 " "
- OVER 150 " "

PLAN No 5

DISTRIBUTION OF TERMINALIA IVORENSIS

COMPARTMENT 32 – USONIGBE FOREST RESERVE



SCALE – 1 : 7,920 or 8 INCHES TO 1 STATUTE MILE

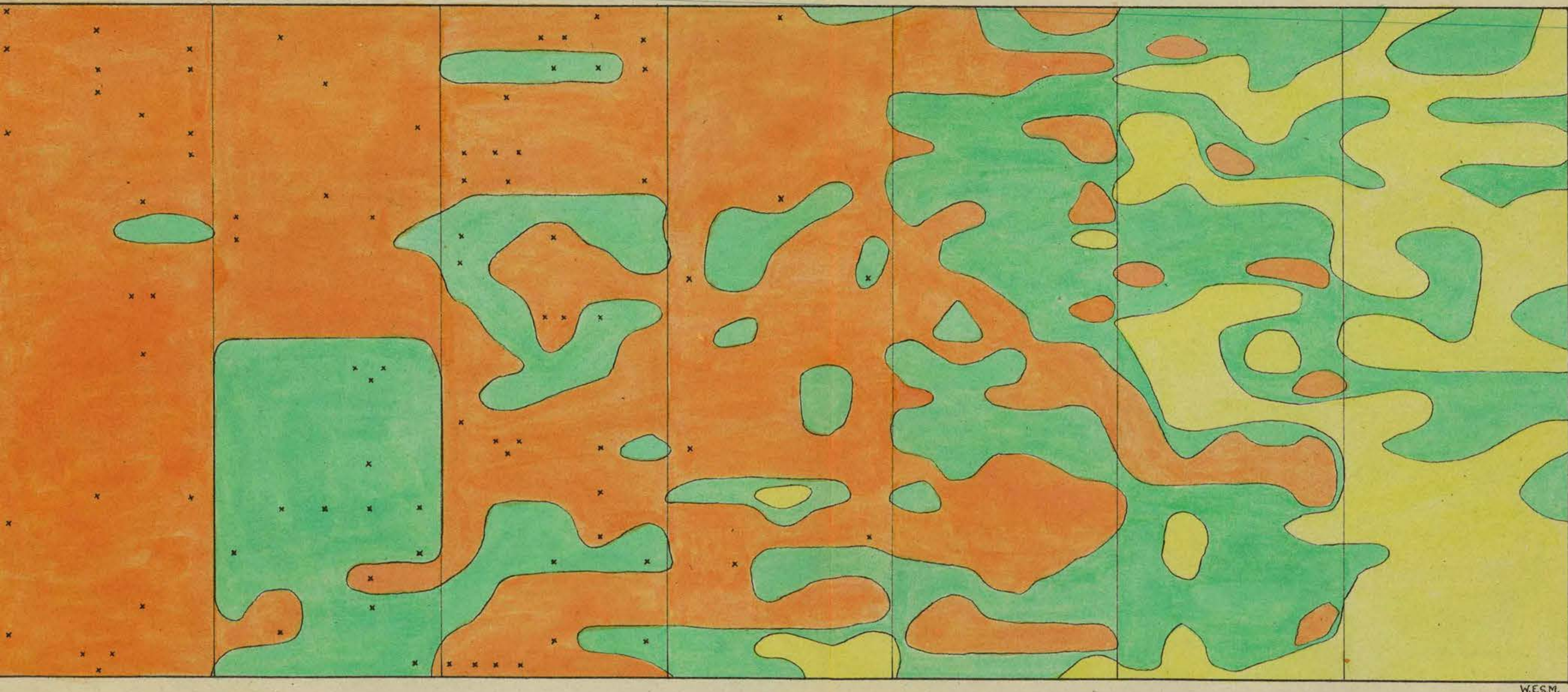
SEEDLINGS AND POLES

Under 25 per acre	
25 to 70 " "	
70 to 150 " "	
Over 150 " "	
MATURE SEED TREES	×

PLAN No 6

DISTRIBUTION OF GUAREA CEDRATA

COMPARTMENT 32 – USONIBE FOREST RESERVE



SCALE – 1 : 7,920 or 8 INCHES TO 1 STATUTE MILE

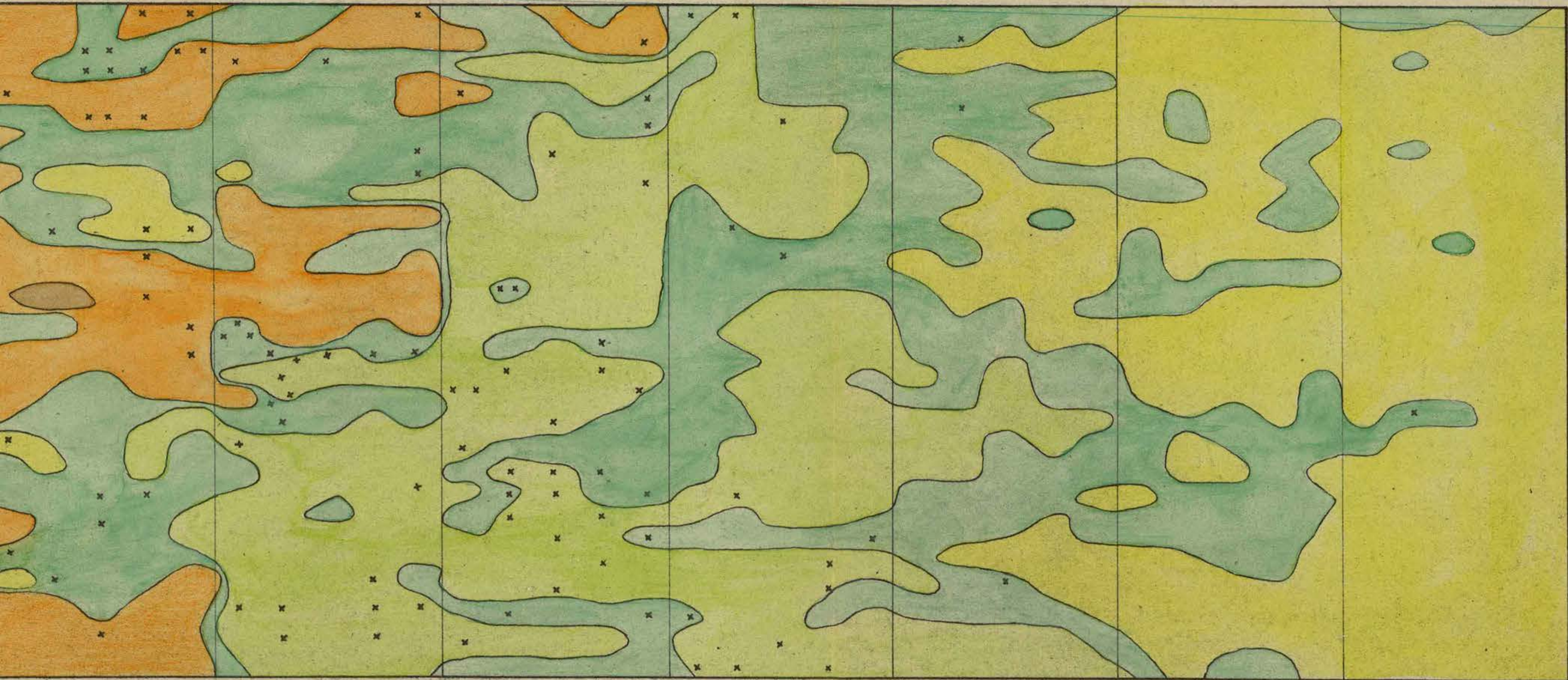
SEEDLINGS AND POLES

UNDER 25 PER ACRE	
25 TO 70 " "	
70 TO 150 " "	
OVER 150 " "	
MATURE SEED TREES	x

PLAN No 7

DISTRIBUTION OF ENTANDROPHRAGMA ANGOLENSE

COMPARTMENT 32 – USONIGBE FOREST RESERVE



W.E.S.M.

SCALE – 1 : 7,920 or 8 INCHES TO 1 STATUTE MILE

SEEDLINGS AND POLES

Under 25 per acre	
25 to 70 " "	
70 to 150 " "	
Over 150 " "	

MATURE SEED TREES ×

PLAN No 8

DISTRIBUTION OF KHAYA IVORENSIS

COMPARTMENT 32 — USONIGBE FOREST RESERVE

W.E.S.M.

SCALE — 1 : 7,920 or 8 INCHES TO 1 STATUTE MILE

SEEDLINGS AND POLES

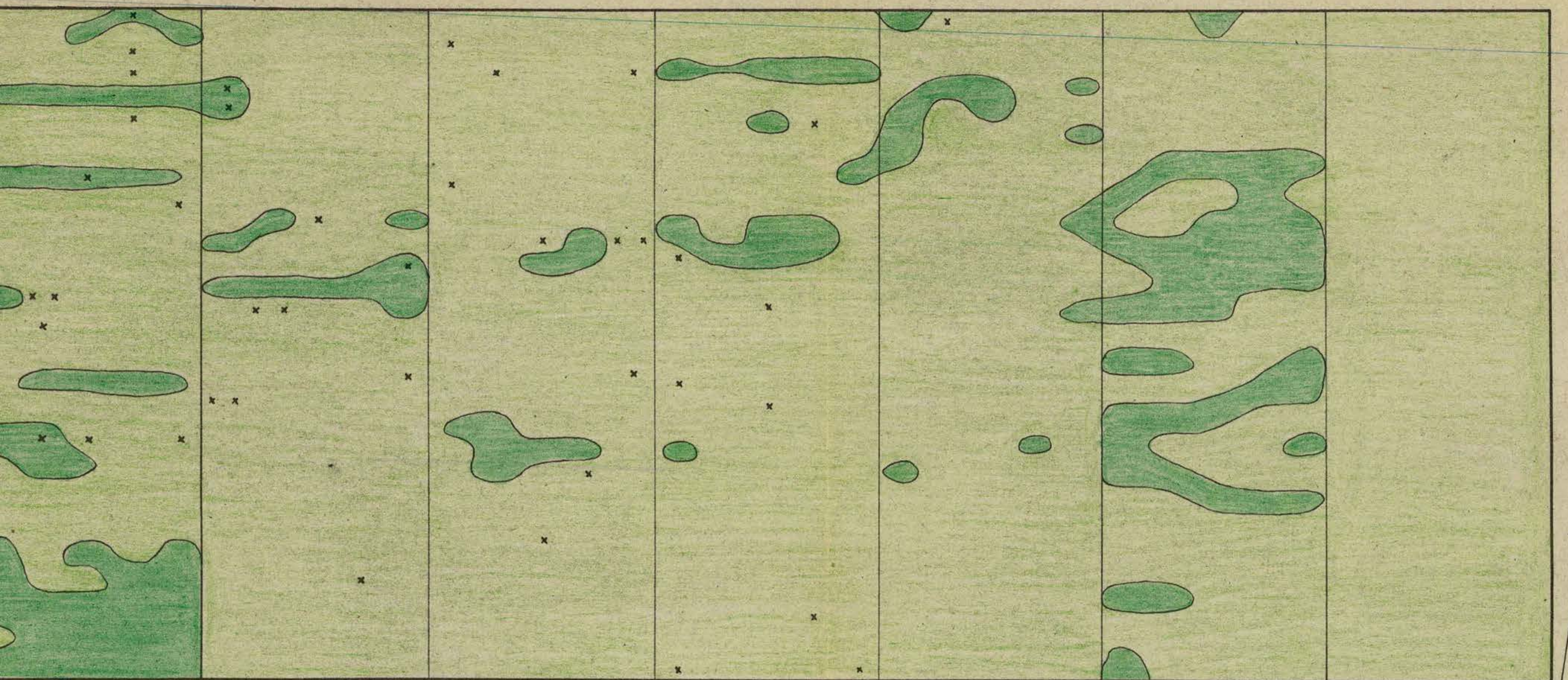
UNDER 25 PER ACRE	
25 TO 70 " "	
70 TO 150 " "	
OVER 150 " "	

MATURE SEED TREES ×

PLAN No 9

DISTRIBUTION OF ENTANDROPHRAGMA CYLINDRICUM

COMPARTMENT 32 – USONIGBE FOREST RESERVE



W.E.S.M.

SCALE – 1 : 7,920 OR 8 INCHES TO 1 STATUTE MILE

SEEDLINGS AND POLES

Under 25 per acre

25 to 70 " "

70 to 150 " "

Over 150 " "

MATURE SEED TREES ×

PLAN No 10

DISTRIBUTION OF TRIPLOCHITON SCLEROXYLON

COMPARTMENT 32 — USONIGBE FOREST RESERVE

SCALE — 1 : 7,920 OR 8 INCHES TO 1 STATUTE MILE

SEEDLINGS AND POLES

Under 25 per acre

25 to 70 " "

70 to 150 " "

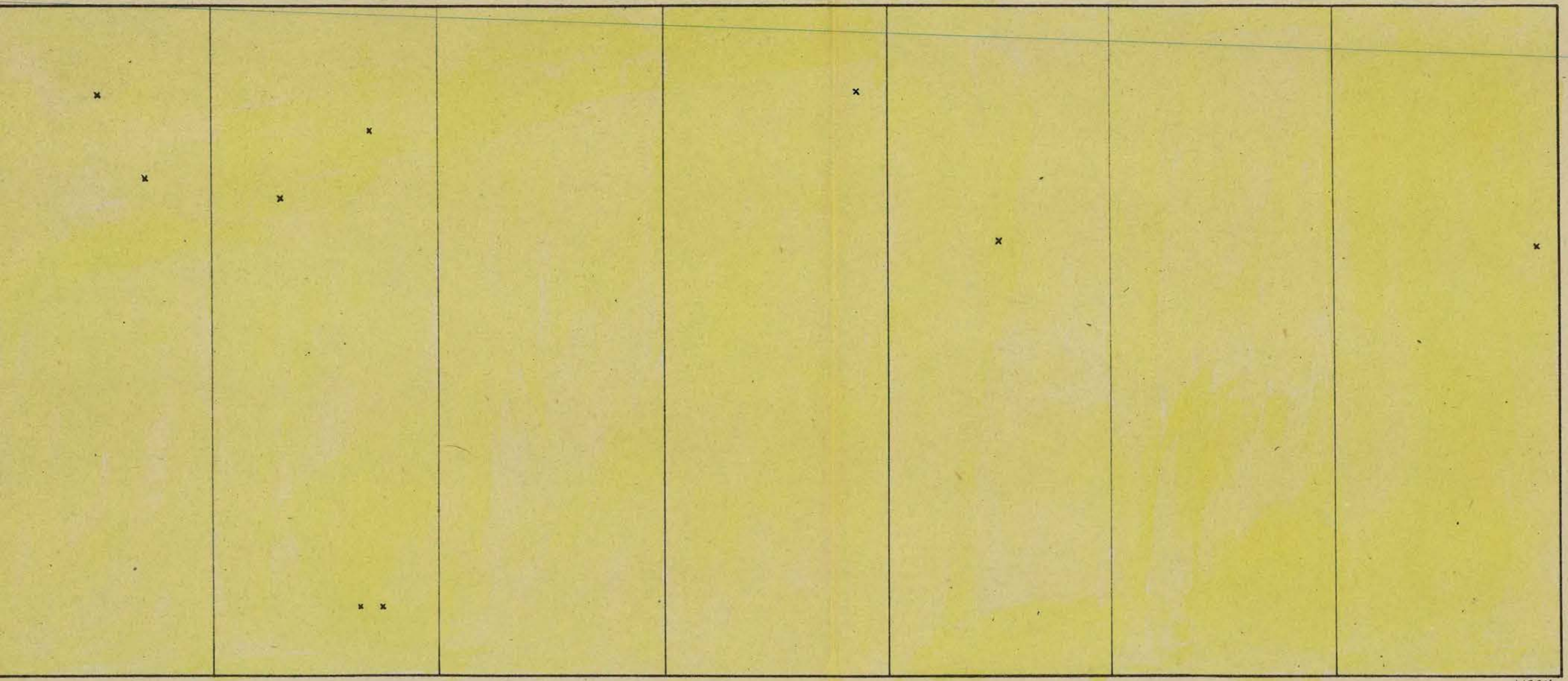
Over 150 " "

MATURE SEED TREES x

PLAN No 11

DISTRIBUTION OF SARCOCEPHALUS DIDERRICHII

COMPARTMENT 32 — USONIGBE FOREST RESERVE



W.E.S.M.

SCALE — 1 : 7,920 or 8 INCHES TO 1 STATUTE MILE

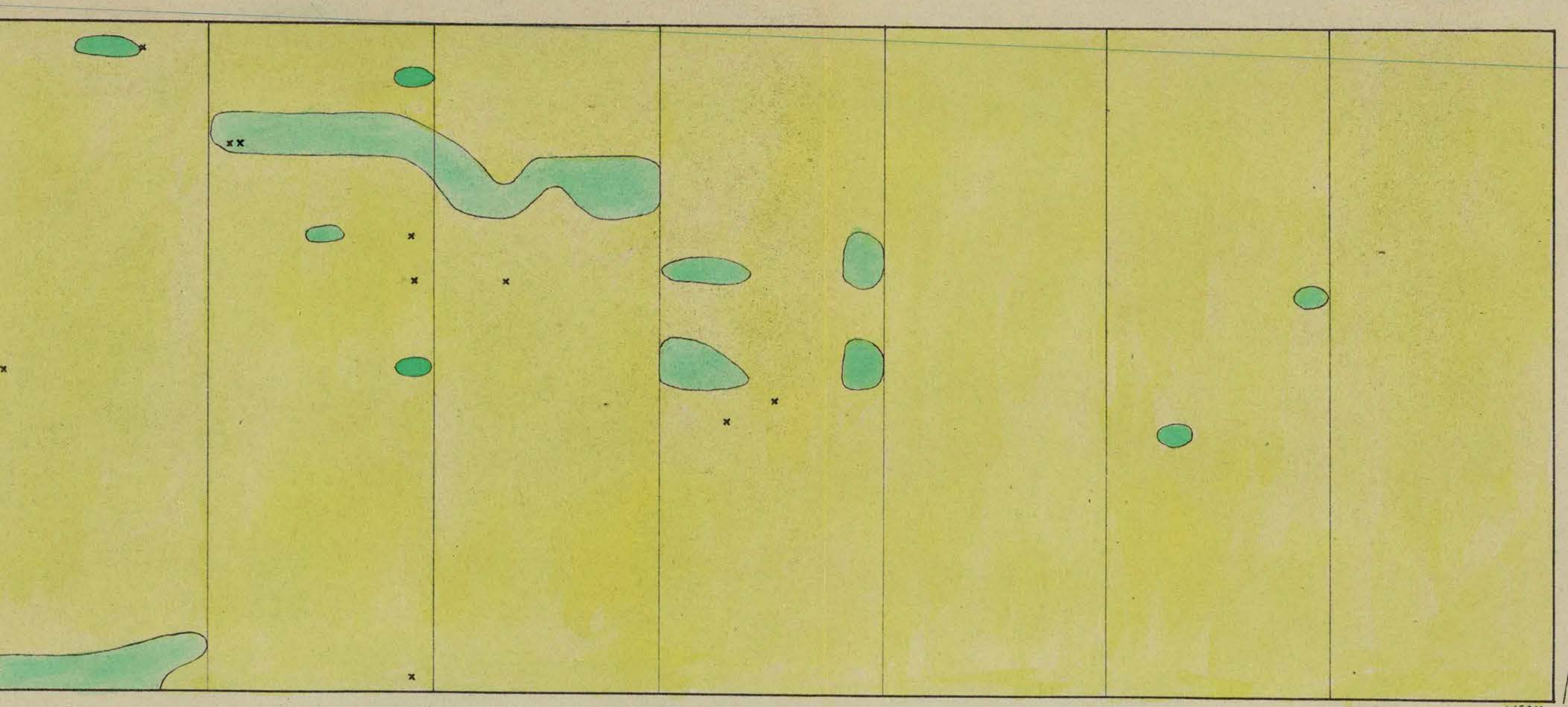
SEEDLINGS AND POLES
Under 25 per acre throughout

MATURE SEED TREES x

PLAN No 12

DISTRIBUTION OF ENTANDROPHRAGMA CANDOLLEI

COMPARTMENT 32 — USONIGBE FOREST RESERVE



SCALE — 1 : 7,920 or 8 INCHES TO 1 STATUTE MILE

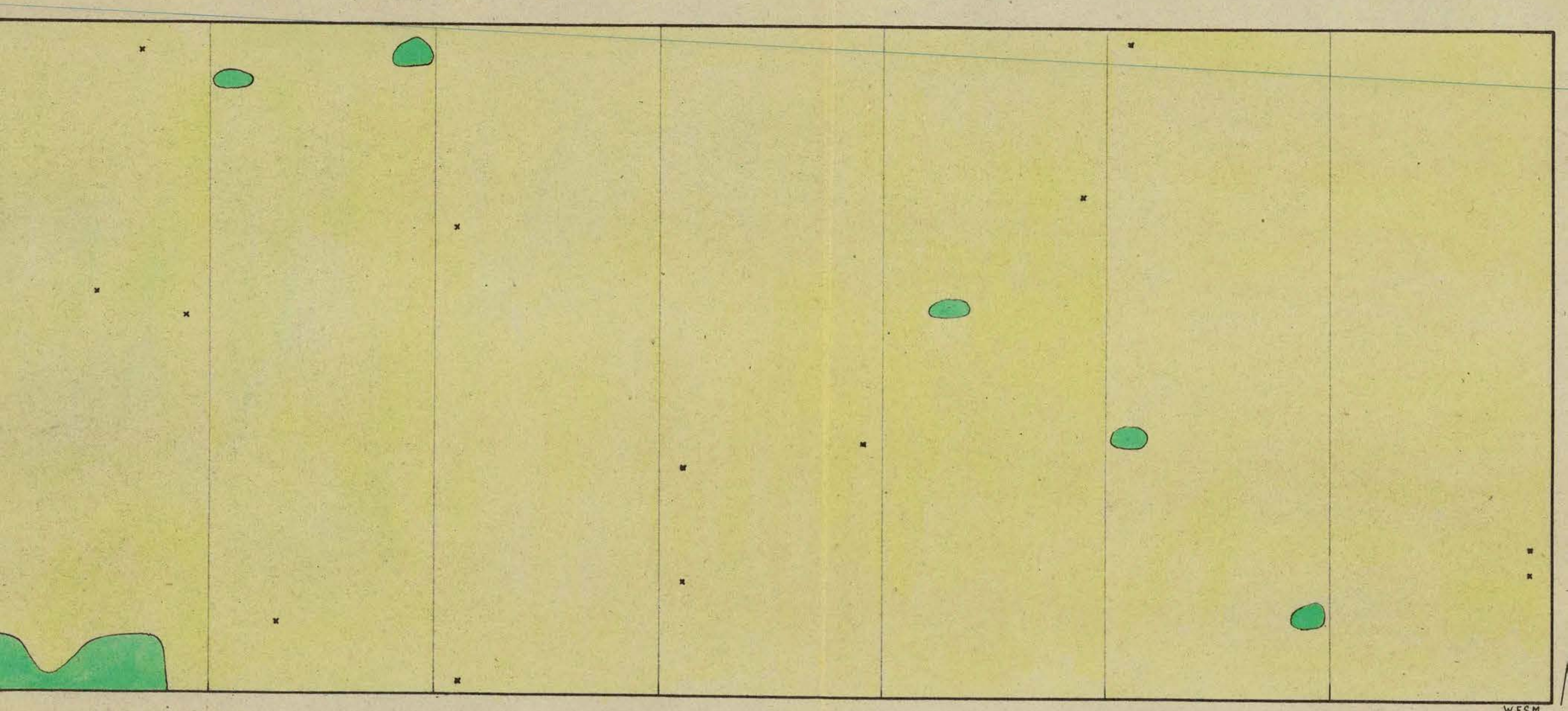
SEEDLINGS and POLES

Under 25 per acre	
25 to 70 " "	
70 to 150 " "	
Over 150 " "	
MATURE SEED TREES	×

PLAN No 13

DISTRIBUTION OF CHLOROPHORA EXCELSA

COMPARTMENT 32 — USONIGBE FOREST RESERVE



SCALE — 1 : 7.920 8 INCHES TO 1 STATUTE MILE

SEEDLINGS AND POLES

UNDER 25 PER ACRE

25 TO 70 " "

70 TO 150 " "

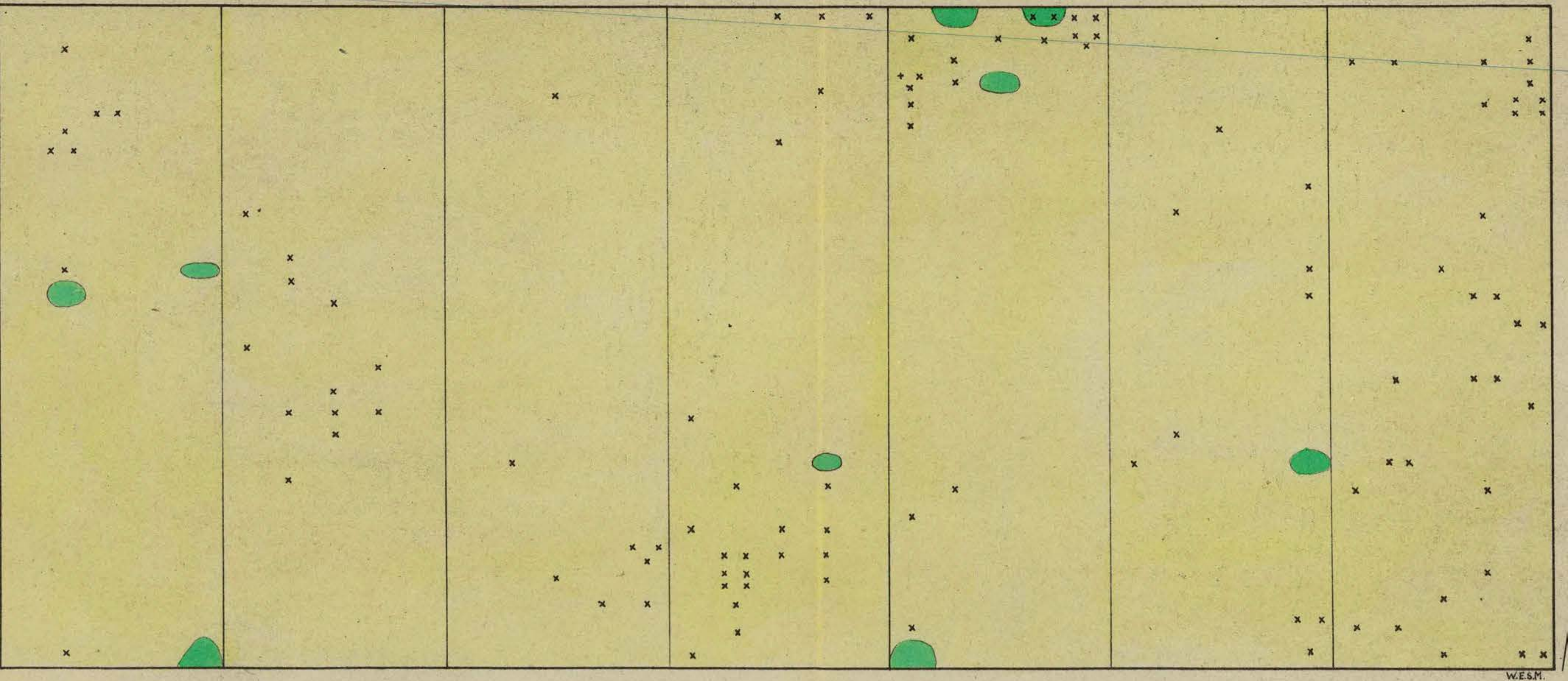
OVER 150 " "

MATURE SEED TREES ×

PLAN No 14

DISTRIBUTION OF TERMINALIA SUPERBA

COMPARTMENT 32 — USONIGBE FOREST RESERVE



SCALE — 1 : 7,920 or 8 INCHES TO 1 STATUTE MILE

SEEDLINGS AND POLES

Under 25 per acre

25 to 70 " "

70 to 150 " "

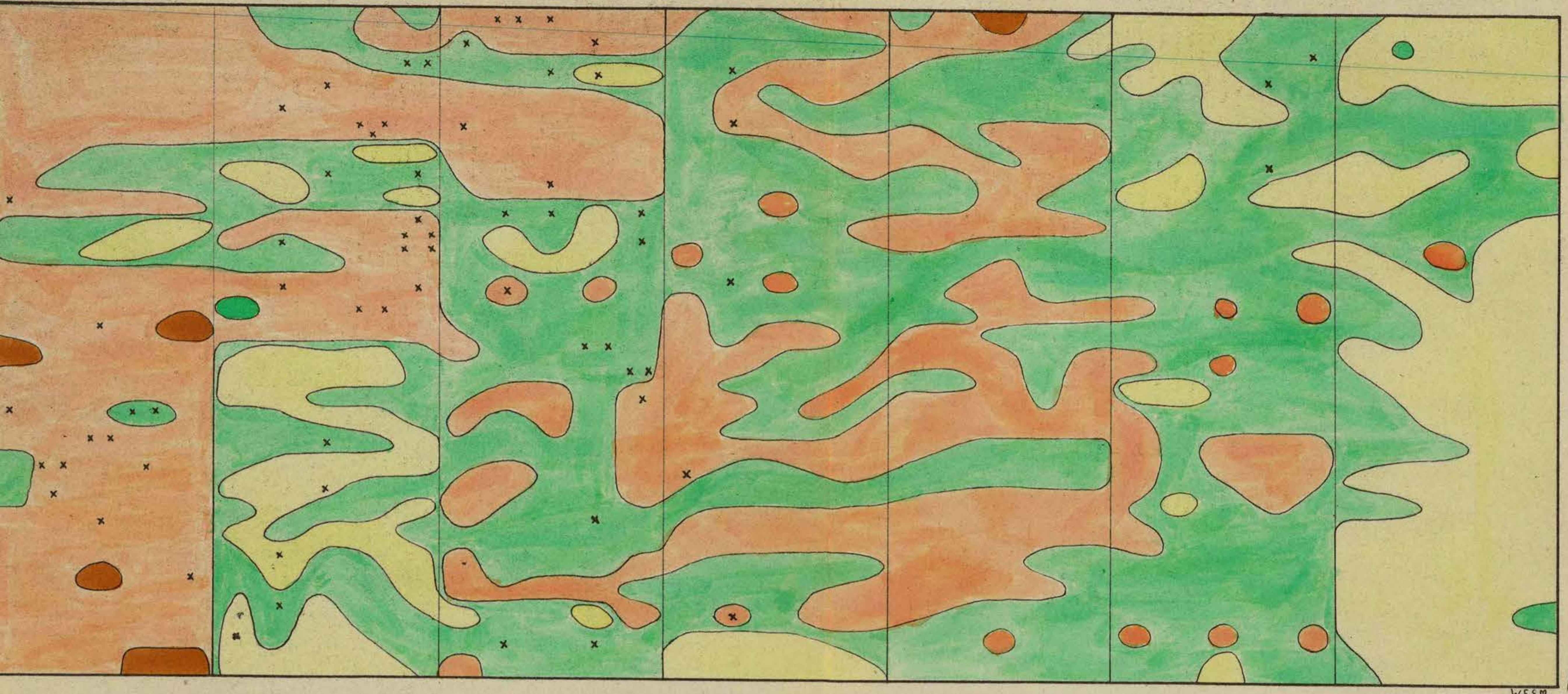
Over 150 " "

MATURE SEED TREES ×

PLAN No 15

DISTRIBUTION OF BERLINIA GRANDIFLORA

COMPARTMENT 32 — USONIGBE FOREST RESERVE



SCALE — 1 : 7,920 OR 8 INCHES TO 1 STATUTE MILE

SEEDLINGS AND POLES

- UNDER 25 PER ACRE
- 25 TO 70 " "
- 70 TO 150 " "
- OVER 150 " "

MATURE SEED TREES x

PLAN No 16.

DISTRIBUTION OF PIPTADENIA AFRICANA

COMPARTMENT 32 — USONIGBE FOREST RESERVE

W.E.S.M.

SCALE — 1 : 7.920 8 INCHES TO 1 STATUTE MILE

SEEDLINGS AND POLES

Under 25 per acre

25 to 70 " "

70 to 150 " "

Over 150 " "

MATURE SEED TREES x

APPENDIX I

LIST OF SPECIES CITED

Acacia pennata Willd.

Acacia ataxacantha DC.

Aframomum sp.

Afzelia bipindensis Harms

Allanblackia floribunda Oliv.

Aningueria robusta Aubrev. & Pellegr. (syn. Malacantha robusta A. Chev.)

Anonidium mannii Engl. & Diels

Antiaris africana Engl.

Antrocaryon sp.

Barteria nigritiana Hook. f.

Berlinia grandiflora Hutch & J.M. Dalz.

Brachystegia spp.

Bridelia spp.

Buchholzia coriacea Engl.

Calamus deeratus Mann & Wendl.

Calpocalyx brevibracteatus Harms

Carapa procera DC.

Ceiba pentandra Gaerth.

Celtis zenkeri Engl.

Chlorophora excelsa Benth. & Hook. f.

Chrysophyllum spp.

Combretodendron africanum Exell

Conopharyngia spp.

Cylicodiscus gabunensis Harms

Dichapetalum spp.

Diospyros atropurpurea Gurke

Diospyros barteri Hiern

Diospyros confertiflora Gurke

Diospyros crassiflora Hiern

Diospyros insculpta Hutch. & J. M. Dalz.

Diospyros piscatoria Gurke

Distemonanthus benthamianus Baill.

Drypetes chevalieri Beille ex Hutch. & J.M.Dalz.

Drypetes principum Hutch.

Enantia chlorantha Oliv.

Entandrophragma angolense (Welw.) C.DC. (syn. E. macrophyllum A. Chev.)

Entandrophragma candollei Harms

Entandrophragma cylindricum Sprague

Fagara spp.

Funtumia africana Stapf

Garcinia polyantha Oliv.

Gossweilerodendron balsamiferum Harms

Grewia coriacea Mast.

Guarea cedrata Pellegrin

Guarea thompsonii Sprague & Hutch.

Hannoa klaineana Pierre & Engl.

Harungana madagascariensis Lam.

Hevea brasiliensis Muell. Arg.

Hylodendron gabunense Taub.

Hymenostegia afzelii Harms

Irvingia gabonensis Baill.

Khaya ivorensis A. Chev.

Lannea acidissima A. Chev.

Lecaniodiscus cupanioides Planch. (incl. sev ral other Sapindaceae?)

Lophira procera A. Chev.

Lovoa klaineana Pierre ex Sprague

"Maba chrysantha" of Kennedy's Forest Flora of S. Nigeria

Macaranga barteri Muell. Arg.

Macrolobium macrophyllum Macbride

Mimusops heckelii Hutch. & J.M. Dalz.

Musanga smithii R. Br. syn. M. cecropioides R. Br.

Myrianthus arb~~o~~oreus P. Beauv.

Newbouldia laevis Seem.

Ochna spp.

Oncocalamus spp.

Ouratea spp.

Pachylobus balsamifera Guillaum.

Panda oleosa Pierre

Pausinystalia johimbe Pierre ex Baille

Picralima nitida Th. & Hel. Dur.

Piptadenia africana Hook. f.

Polyalthia suaveolens Engl. & Diels

Randia cladantha K. Schum.

Randia spp.

Ricinodendron africanum Muell. Arg.

Rinorea spp.

Sarcocephalus diderrichii De Wild.

Scottellia coriacea A. Chev.

Sersalisia micrantha Aubrev. & Pellegr.

Staudtia stipitata Warb.

Sterculia oblonga Mast.

Sterculia rhinopetala K. Schum.

Sterculia tragacantha Lindl.

Strombosia grandifolia Hook. f.

Strombosia pustulata Oliv.

Terminalia ivorensis A. Chev.

Terminalia superba Engl. & Diels

Tetrorchidium didymostemon Pax & K. Hoffm.

Treculia spp.

Trema guineensis Ficalho

Trichilia prieuriana A. Juss.

Triplochiton schleroxylon K. Schum.

Vitex spp.

Xylopia spp.